DEVELOPMENT AND EXPERIMENTAL EVALUATION OF AN AUTOMATED MULTI-MEDIA COURSE ON TRANSISTORS

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FOREWORD

This report represents a portion of the exploratory development program of the Technical Training Branch, Training Research Division, Behavioral Sciences Laboratory, Aerospace Medical Research Laboratories. The research was performed in support of project 1710, "Human Factors in the Design of Training Systems," task 171007, "Automated Training and Programmed Instruction." Dr. Gordon A. Eckstrand was the project scientist and Dr. Ross L. Morgan was the task scientist. The research was begun in April 1965 and completed in June 1966.

This report covers the research conducted in part under contract AF 33(615)-2880 by the RCA Service Company, Division of Radio Corp of America, Cherry Hill, Delaware Township, Camden, N. J. 08101. Mr. John H. Whitted, Jr. was principal investigator for the RCA Service Company. The contract was initiated by Dr. John S. Abma. Mr. John P. Foley, Jr. served as the Air Force technical contract monitor for the Aerospace Medical Research Laboratories.

Gratitude is due to Mr. William L. Patty and Mr. Wayne C. Zimmerman of the Career Development Branch of the Civilian Personnel Office, Wright-Patterson Air Force Base, Ohio for their concurrence with the project and their special efforts in programming sufficient students for the experiment. Special recognition is due Mr. Walter C. Laudig of the same office who taught the classroom/laboratory group of the experiment and all three groups for the follow-on portion of the experiment. His efforts in furnishing training materials and other course information and in keeping adequate records contributed substantially to the success of this research.

Gratitude is due the Fairchild Industrial Products Division of Fairchild Camera and Instrument Corporation for the free loan of two Fairchild Mark IV projectors. Gratitude is also due to Miss Patricia Wetzel who helped with the statistical calculations. Special thanks are due to Dr. Edgar A. Smith of the Technical Training Branch for his technical advice concerning the operation and maintenance of the audio-visual devices used during this experiment. He contributed greatly to the operational success of the multi-media instructional procedures.

This technical report has been reviewed and is approved.

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ABSTRACT

A completely automated multi-media self-study program for teaching a portion of electronic solid-state fundamentals was developed. The subject matter areas included were fundamental theory of transistors, transistor amplifier fundamentals, and simple mathematical analysis of transistors including equivalent circuits, parameters, and characteristic curves. The media included tape slide audio-visual presentations, a programmed text, a cued text, a sound movie, a workbook, and an RCA transistor trainer. A controlled experiment was conducted, comparing the effectiveness of the self-sufficient multi-media materials, with a conventional instructor/classroom presentation and existing self-study materials from Air Force Extension Course Institute. Even though the instructor/classroom subjects received somewhat higher ratio gain scores, on the average, than the multi-media subjects, this difference was not significant. Both of these modes were superior in effectiveness to the extension course materials. The principal measures of this effectiveness were a pre-test and a post-test made up of multiple choice items concerning the solid state theory covered.

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SECTION I
INTRODUCTION

This research was directed toward determining the feasibility of effective training on technical subjects utilizing a variety of instructional media in completely self-study courses. Substantial cost savings may be realized from the employment of effective self-study programs in the following areas: reduced requirements for trained instructors, more efficient use of available instructors, reduction in cost of acquisition and maintenance of training facilities, reductions in cost of transportation to and maintenance of trainees at the training location, and the capability of reaching a wider audience by delivering the course to the trainee even at a remote duty station.

Formal self-study courses certainly are not unique in technical training. For example, correspondence courses are available on virtually any technical subject desired and more are being developed and revised to keep pace with advancing technology. A weakness often sighted concerning conventional self-study programs is the difficulty of maintaining a high level of trainee motivation throughout the course, especially if the course is rather lengthy.

Other apparent weaknesses of conventional self-study courses are the lack of assurance that intended concepts are learned without misunderstanding and assurance that the training material will reach the widest possible audience without sacrifice of effectiveness for any one individual in the range of intended aptitudes. All of these would seem to argue against the feasibility of efficient self-study programs. However, these difficulties may be overcome by modernizing the approaches to course construction and utilization of appropriate modern media. It is hypothesized that, for at least some technical subjects, self-study courses can be made at least as effective as traditional methods and for some subjects even more effective.

Assuming that one of the basic problems in self-study is the maintenance of a high level of student motivation throughout the course, three basic approaches are suggested to overcome such difficulty with conventional self-study courses. First, the presentation of material, especially abstract ideas and concepts, in an interesting, indeed entertaining manner, should capture the students' interest. Second, the employment of a different or modified medium for each section of the course should break the monotony inherent in a course utilizing only one or two instructional methods. Third, by repeating and building upon the most important basic concepts in each medium a wider range of trainee abilities

might be reached. The danger here, however, is the possibility of too much repetition boring the higher ability-level trainees. Therefore, a very judicious use of repetition and subtlety in application is very essential. Fourth, the incorporation of extensive requirements for active student participation and reinforcement should keep the student alert and allow him to gauge his own progress through the course.

Another weakness found in many traditional self-study programs is the lack of accommodation of material to a variety of trainee personalities and individual interests. It is hypothesized that the multi-media approach would reach a wider range of learning abilities and self-interests, especially when applied to predominantly verbal material. For example, an audio visual approach might be most appropriate for one group of students while a text might be better for another group. Bush et al, [1] found that students with relative strength in reading vocabulary were superior to students with relative strength in Mathematic Fundamentals when both were required to learn from instructional conditions that were highly verbal. On the other hand, students with relatively strong Mathematic Fundamentals tend to learn more efficiently in individual laboratory situations. Also, by presenting the material in such a manner as to build upon a wide range of expected student repetoires a higher degree of student interest can be maintained. Further, the use of analogies for presenting abstract phenomena and the liberal application of the important concepts to different tangible areas of interest probably would appeal to the self-interest of a greater range of students.

The general purpose of the effort described in this report was to determine the feasibility of developing completely automated self-study courses that would avoid some of these apparent weaknesses of existing self-study courses. A multi-media, automated course on the fundamentals of transistors was developed and experimentally evaluated.

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[1] Bush, Wilma S.; Gregg, Dolores Kathryn; Smith, E. A.; McBride, C. B., Some Interactions Between Individual Differences and Modes of Instruction, AMRL - Technical Report 65-228, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio 1965

SECTION II
PROBLEM

The problems to which this research effort was directed were: (1) to determine the feasibility of developing a completely automated self-study program of instruction for teaching electronic solid-state fundamentals, and (2) to determine by means of a controlled experiment, the relative effectiveness of this completely automated self-study course compared to two traditional modes for teaching the same materials, namely classroom/instructor mode and a conventional self-study mode.

Since the automated self-study course was to be compared with other existing courses, both the content and sequence of all courses was as similar as practical.

SECTION III

DEVELOPMENT OF MULTI-MEDIA SELF-STUDY PROGRAM

1. MATERIALS

The first 24 hours of a course on the fundamentals of transistors at Wright-Patterson AFB was selected as the basic content of the course to be developed. Selection of this portion of the course offered the following advantages over selection of any other portion of the course:

(1) Pre-training test scores would not be influenced by relative success in immediately preceeding training.

(2) Since students would progress at their own rate in the experimental course they would complete the experimental course at different times. This variation in time of readiness for subsequent classroom training was most easily accommodated early in the 100 hour course.

(3) The first section of the course seemed to allow more flexibility in the application of a variety of instructional media.

The basic ground rules for development of the experimental course were that the experimental program would:

(1) employ as many different instructional media as practicable;

(2) be completely self-study without instructor assistance;

(3) be essentially a conventional linear approach, similar to the classroom presentation and;

(4) utilize or adopt devices, facilities and materials readily available to the extent possible, with the development of new devices or unique environments excluded.

Following the selection of the first 24 hour portion, the exact objectives of this section were established. These were derived from a complete course outline (See Appendix II) on the existing classroom course along with a list of applicable training aids and materials. A thorough teaching point outline was then compiled for the experimental course (which represents the material taught in the first 24 hours of the classroom course). The instructor of the classroom course reviewed the course objectives and teaching outline and agreed that they were consistent with the classroom course.

The next step was to develop a production flow diagram for development of the experimental program. The production flow diagram provided a reference for maintaining story line continuity as well as highlighting potential problem areas in effecting smooth transitions from one instructional medium to another. Initially, the flow diagram merely divided the course into eight logical course sections. This flow diagram including major course sections as well as subsections is depicted in Appendix I. Although the course could have been divided into somewhat fewer sections, eight were finally selected because this allowed the application of a greater variety of media.

After careful review of the material to be taught in each section, a tentative assignment of method and/or medium for each section was made. Ideal media were considered to be those which met the following criteria:

(1) clarity of presentation of the particular material, e. g. abstract concepts, purely theoretical ideas, requirements for motion, etc.;

(2) dramatic and/or novel effect;

(3) interest and motivation provoking aspects;

(4) requirement for student response and participation; and

(5) ability to relate concepts being taught to tangible transistor equipments and components.

It was realized at the time these assignments were made that, within the budgetary limits of the program, adjustments would have to be made before final selection of material for each course section. This, however, did form the basis for a survey, of available devices, material and methods which was the next step in program preparation.

Construction and assembly of course material was begun on Section B "Semiconductor Physics". It was decided to prepare Section A "Introduction" last so that the introduction could include descriptions of the study procedures to be employed after they had actually been selected and developed. This also would permit the use of actual course material as the subject of visuals to be used in previewing the whole course.

a. Section B, "Semiconductor Physics"

It was decided that a good audio-visual type presentation had the greatest merit for employment in section B, "Semiconductor Physics" for the following salient reasons:

(1) The liberal use of visuals to impart some of the rather obscure and abstract concepts such as structure of matter, crystal structure and the conduction processes within crystalline materials, would overcome the inherent difficulties in getting these concepts across to the widest range of abilities and backgrounds of potential students. It was determined early in the program that the course may have to be presented to students with little or no prerequisite fundamental electronic background, as well as to students with considerable background.

(2) In order to start at an elementary level and still avoid alienating the student having considerable fundamental knowledge, the audio-visual approach seemed to offer considerable advantage from the entertainment and review standpoint to offset this possibility. Also, the most elementary principles could be presented at a relatively fast pace for those already familiar with them.

A survey of industry and other sources failed to reveal a source of audio-visual materials which met the requirements of section B without seriously compromising the teaching effectiveness of this section. This section and section A "Introduction", was virtually the start of the course and would be a tremendous factor in the establishment of student attitude. It was therefore decided to custom produce this material specifically for the experimental course to enhance its motivational value.

All self instructional audio-visual material for the experimental program was produced and programmed for the Graflex "Audio-Graphic Instructor".

b. Section C, "Junction Theory"

The choice of a linear programmed text for section C was based on several factors, one of which was the availability of a thoroughly tested program. Other factors influencing the choice of this material for section C were:

(1) It would facilitate the translation of purely theoretical concepts, presented in section B, to the behavior of the simplest of semi-conductor devices, the diode.

(2) It would serve to thoroughly emphasize and reinforce the vocabulary and terminology of the semiconductor field presented in section B before further extending and applying the terms to actual devices and circuitry.

(3) Since the experimental course was to employ multimedia, including programmed text material, this was the most appropriate section of the course for its employment. Especially in view of the various backgrounds of the intended audience this self-pacing material seemed appropriate to the establishment of basic semiconductor concepts. Its language level seemed appropriate for the full range of students expected to take the course.

Section C was supplemented by seven audio-visual review and self-test sequences. These had a three-fold purpose:

(1) to ensure communications and the understanding of the most important concepts to the widest audience.

(2) to allow the student to gauge his own understanding and progress, and

(3) to ensure active student participation in his learning of the course material.

c. Section D, "Principles of Transistor Action"

Text material was to be included as one of the media in the experimental course. By this time the student should have gained enough real understanding of transistor terminology to handle text material more readily than earlier in the program. It was, therefore, chosen for section D. After a review of various text books on the subject area none were found which were completely satisfactory. To select existing conventional material would, in fact, have detracted from what was considered to be an optimum approach to automated instruction throughout the rest of the program. It was decided then to prepare the material using a "cued" form of text in order to enhance the learning effectiveness. For a sample of "cued" text, see Appendix IX.

The fundamentals of circuit arrangement, schematic symbology, and elementary computations were introduced at this point in the course. The introduction to and direction for handling of actual transistor circuit components was also included in section D.

This section also formed a composite of material presented up to this time and presented it within a realistic framework. This section was designed to provide a readily accessable reference to be used for review without having to go back to the prior sections of the course.

The text developed includes various methods of prompts and cues to emphasize the most important concepts, and frequent review and self-tests to assure active student participation. An attempt was also made to write the material in the simplest language and emphasize the building of vocabulary in the technical terms peculiar to semiconductor technology. Extensive theoretical dissertation supporting the concepts presented was purposely avoided since it was considered that this peripheral knowledge would only cloud the issue at this level.

d. Section E, "Review and Progress Measurement"

A sound motion picture approach was chosen for this section for the following reasons:

(1) Up to this point in the course the student had been required to interpret verbal instruction and static visual presentation in terms of motion and dynamic behavior. A good animated motion picture would serve to clarify these dynamic concepts, avoid any misconceptions in the mind of some of the students, and form a good preview of the course material to follow which investigates various parameters of transistor circuitry.

(2) The entertainment aspects of an interesting sound motion picture at this point in the course formed a welcome interlude to the student after the relative tedium of the text material just preceeding this section. A re-awakening of possibly waning motivation was thought to be most appropriate at this point in the course.

(3) A broadening of knowledge and a greater appreciation for the whole semiconductor field could also contribute to a reawakening of student interest in the subject. Although the film "453 Steps" contributed little direct essential knowledge to semiconductor theory, its motivational and interest enlivening attributes are considered to be indispensible. It was also felt that this film imparts valuable indication of interest in the student on the part of the program producers.

Two sound motion pictures were chosen for this section. They are: "Transistor Fundamentals" (22 min. B/W) and "453 Steps" (30 min. color).[2] These films were available off the shelf in 16 mm version. They were reprocessed into 8 mm and packaged into cartridges for use in the "Fairchild Mark IV" student operated presentation unit.

A self-evaluation unit was included at this point to assure the student that he was prepared for future course materials. A set of standards were provided to compare his understanding with that required for further progress.

e. Section F, "Transistor Amplifier Analysis"

A work book format was selected for this course section in order to allow the student to gain a degree of proficiency in recognition and use of circuit symbology, computation and graphic representation of circuit behavior, and to reinforce the basic rules of transistor circuit arrangements.

This section was also intended to serve as a transition from the purely verbal and symbolic instruction employed to this point, to the application of principles, actual circuit construction, and measurement which occur in the last section.

The work book required that the student complete circuit diagrams, compute circuit parameters and graphically plot dynamic circuit characteristics. The student received immediate reinforcement for each step he completed as well as composite reinforcement for the total concepts presented.

As no suitable material was found, this section was constructed expressly for the experimental course.

f. Section G, "Diode and Transistor Behavior"

Actually two instructional media were integrated in this section; a transistor circuit trainer (RCA 601-T) and audio-visual. The predominant reason for selecting these media of instruction was to obtain the greatest concentration by

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[2] RCA Semiconductor Division, <u>Transistor Fundamentals</u>, film produced by Bray Studios, Inc., 729 Seventh Ave., New York, N. Y. 10019. RCA Semiconductor Division, <u>453 Steps</u>, film produced by RCA Semiconductor Division, Somerville, N. J., Mr. George De Zayas, producer.

the student on the physical aspects of circuit arrangement and instrument reading so as to enhance his learning. This would eliminate the division of attention between the trainer and a text such as an experimental guide. However, careful attention had to be given to the construction of the aural material so that a high probability of reaching all students, even those with lower verbal aptitudes, could be attained.

The instruction in this section was devoted to the practical aspects of fundamental semiconductor phenomena. The student was required to construct simple circuits, vary parameters and observe results. Further, he is required to predict reaction to varying parameters and verify his predictions by actual measurements. The student received comprehensive aural instruction for each step in the set up of the circuits and measurement of the various circuit parameters. A minimum amount of visual supplement was included at critical points in the instruction. Composite visual and aural summarization was provided after the student had performed sufficient measurement so as to be able to arrive at a conclusion. Aural discussion-type reviews were held after each experiment or a portion of an experiment which demonstrated a particular behavioral concept. This was done in order to ensure that intended conclusions were in fact reached by the student and, if not, to clarify any misconceptions before proceeding to the next experiment.

Four experiments were included which ranged from a basic investigation of the diode through the construction, measurement and graphic representation for the varying parameters of an actual transistor amplifier in operation.

The experiments and direction for their procedure were extracted from the experimental guide which accompanies each RCA 601-T Transistor Trainer. A draft script was written and underwent extensive tryout with the Audio Graphic to assure that instructions were valid and that intended results would be obtained from the trainers. After necessary revisions, the required audio-visual materials were again tested.

g. Section A, "Course Introduction"

As mentioned previously, this section of the experimental course was the last to undergo development. An ideal approach would have been to use sound color motion pictures. This approach offered the greatest advantage for capturing student attention and establishing a high level of initial motivation. (This, of course, was an application of the old adage that initial impressions are the most lasting). This

film would have had to be dramatic and appeal to the self-interest of a wide audience. To increase palatability it would have included humor and other entertainment aspects as well as some technical information although this latter requirement was rather secondary. Information content would have been restricted to historical background, general application of the technology, and present and future impact on everyday life. The need to learn something of this technology would compose a subtle theme throughout this introduction.

After a thorough review of all time and cost factors involved in production of such an introductory movie, it was evident that production of this movie was not possible. The only alternate method which approached meeting the criteria cited above was an audio-visual presentation using still pictures. Some sacrifice in dynamism would have to be made but by altering the original approach so as to reduce or eliminate the need for motion it was felt that the criteria could almost be met using still visuals.

Having arrived at these conclusions the next step was preparation of a draft script and development of a pilot introduction sequence which used the guide lines described above without motion. After trial and revision it was finalized.

h. Training Manual

As a guide to the student through his instructional sequence, a training manual was developed. The complete experimental course was, of necessity, developed in discrete sections. However, great attention was given to the method of transition from one section (and medium) to the next. At all times explicit direction for procedure to the next section was included at the end of the medium currently in use. To prevent the dissociation and lack of organization that was inherent in this program, the central point source of reference for the course was the training manual. It not only contained all printed study material for the course under one cover but also supplemented the procedural direction included in the machine sequences.

For each section of the course there was a section in the manual. Each section began with complete direction for procedure within that section and concluded with direction for procedure to the next section. In addition, a list of all materials required by the student while actively participating in the program was included in the appropriate manual section. The manual contained a total of 218 pages. The training manual can be seen in use in Figure 1.

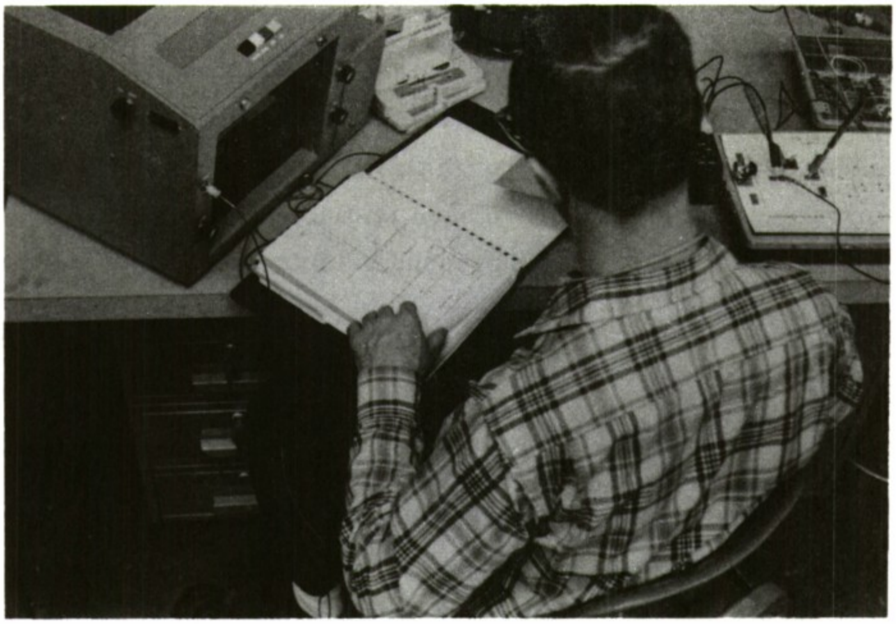

Figure 1. Student Using Training Manual

i. Summary

In summary, the experimental materials were produced and tested in discrete sections. Each section, after test, revision and validation, was finalized and integrated into the main stream of the complete course. Although rigorous testing methods were not employed each section was administered to from five to ten subjects so as to either validate the original approach or provide the basis for revision.

The basic philosophy guiding the construction of this course can be summarized in the following major considerations:

(1) create and maintain a high degree of student motivation,

(2) maintain clarity of verbal instruction to insure comprehension,

(3) maintain the entertainment quality as high as possible,

(4) include sufficient challenge to the student while attempting to ensure that the challenge is within his currently attained normal repertoire of behavior, and not likely to frustrate him,

(5) include provision for active student participation to the extent practicable,

(6) provide liberal opportunity for encouragement by way of self-test and progress measurement, and

(7) liberal use of preview-review technique so that the student will always know where he has been, where he is and where he is going.

2. EQUIPMENT

The special equipment utilized in the experimental course consists of the Graflex "Audio-Graphic Instructor", the Fairchild Mark IV 8 mm sound motion picture presentation unit, the RCA 601-T Transistor Trainer, the RCA WV77E vacuum tube voltmeter, the RCA WV38A multimeter and, of course, the Training Manual. Six student positions were equipped with the above equipment (except for the Mark IV machines of which there were only two). A typical student position in operation is depicted in Figure 2.

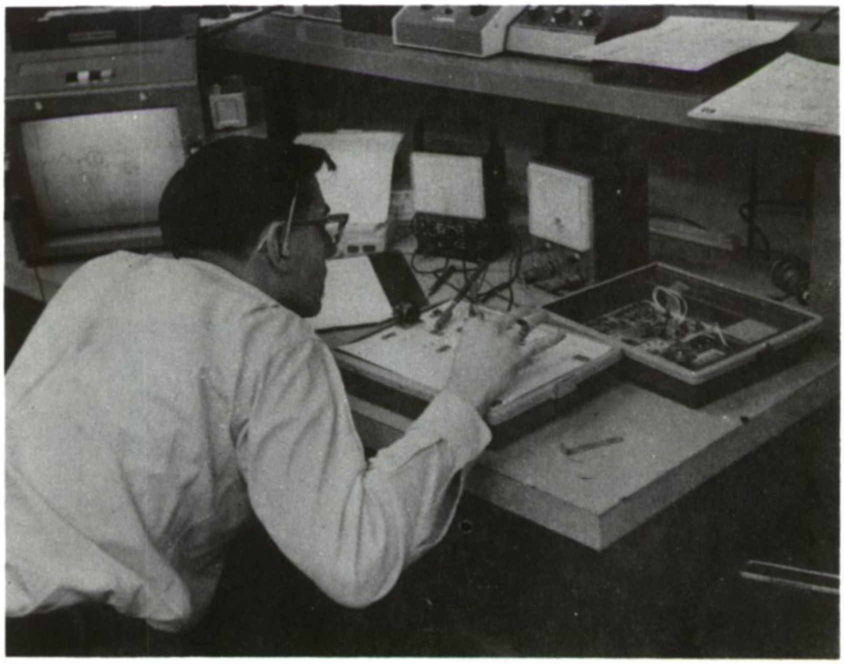

Figure 2. Typical Student Position

The Graflex Audio-Graphic Instructor is a completely student operated audio-visual presentation unit. Lectures are recorded on magnetic tapes which are enclosed in cartridges. Each cartridge is reversible and contains 30 min. of sound per side. The synchronsim between the sound and the accompanying visual material is accomplished by inaudible pulses recorded on the tape. A total of 4-1/2 tape cartridges were used for the audio-visual portion of the program. The sound output is by way of either a speaker or headphones which disable the speaker when plugged in. Headphones were used exclusively for the program to eliminate adjacent student position interference.

The visual material consists of 35 mm color slides which are contained in cartridges accommodating 36 slides each. The change from one slide to the next is accomplished automatically by the tape impulses as mentioned above. The picture is presented by means of rear screen projection on the front panel of the instructor. A total of 8 slide cartridges (288 slides) were used for the program.

The Fairchild Mark IV is a completely self-contained student operated sound motion picture viewing unit. Eight millimeter sound motion picture films are processed into an endless belt arrangement and housed in cartridges. This precludes any difficulty of threading or rewinding. The student merely inserts the cartridge and operates the start control. Sound is provided either via a loud speaker or headphones. Headphones were used for administration of this program.

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Figure 3. The Fairchild Mark IV Unit in Operation

Two machines were set up in an area apart from the main study area (containing the six student positions) so as to minimize the distracting effect of this presentation method on those students who were studying other course materials. The actual use of this machine during the program's administration is depicted in Figure 3.

The RCA 601-T Transistor Trainer is a self-contained unit containing a kit of electronic parts, a pre-wired jack field and a set of 12 templates which provide for the construction of twelve different circuits. To construct the circuits and observe their reaction to varying circuit parameters the student places a template over the jack field and plugs in the specified components. He then makes the prescribed adjustments and records the readings he observes on his two instruments in the appropriate spaces in his training manual.

The two instruments, the RCA WV77E Vacuum Tube Voltmeter and the RCA WV38A Multimeter, were used for measuring voltages and currents in conjunction with the Transistor Trainer. These are fairly common type test instruments found in the most elementary test and maintenance shops. The WV77E is used mostly for measuring small variations in voltages usually on the 1.5 volt scale where values of .17 to .25 volts are common in performing the experiments. The WV38A is used mostly for measuring small values of current. For most of the measurements either the 50 microamp or 1 milliamp ranges are used. Figure 2 also depicts the Transistor Trainer, along with the instruments, actually in use by a student.

Table I depicts the mode of presentation employed in each section of the experimental program.

TABLE I

Course Content vs. Media

	Tape/ Slide (A/V)	Programmed Text	Cued Text/ Narrative	Sound Movie	Work book	Transistor Trainer
Section A Introduction	I					
Section B Semiconductor Physics	I, R					
Section C Junction Diodes	R	I				
Section D Principles of Transistor Action			I, R			
Section E Review and Progress Measurement			R	I, R		
Section F Transistor Amplifier Analysis					A, R	
Section G Diode and Transistor Behavior	A, I					P

Legend

I - New Information

R - Review Information

A - Theoretical Application

P - Practical Application

SECTION IV

DESCRIPTION OF EXPERIMENT

1. EXPERIMENTAL DESIGN

A randomized blocks analysis of variance design was used.[3] The randomized blocks of subjects were formed on the basis of learning ability as measured on Form A of the Otis Self Scoring Test of Mental Ability. The independent variable was the mode of presentation. Three tests were used in the measure of student achievement, a pre-test, and post-test (after 24 hours of training) and a final test at the end of the course (102 hours of training). The design is shown in Figure 4.

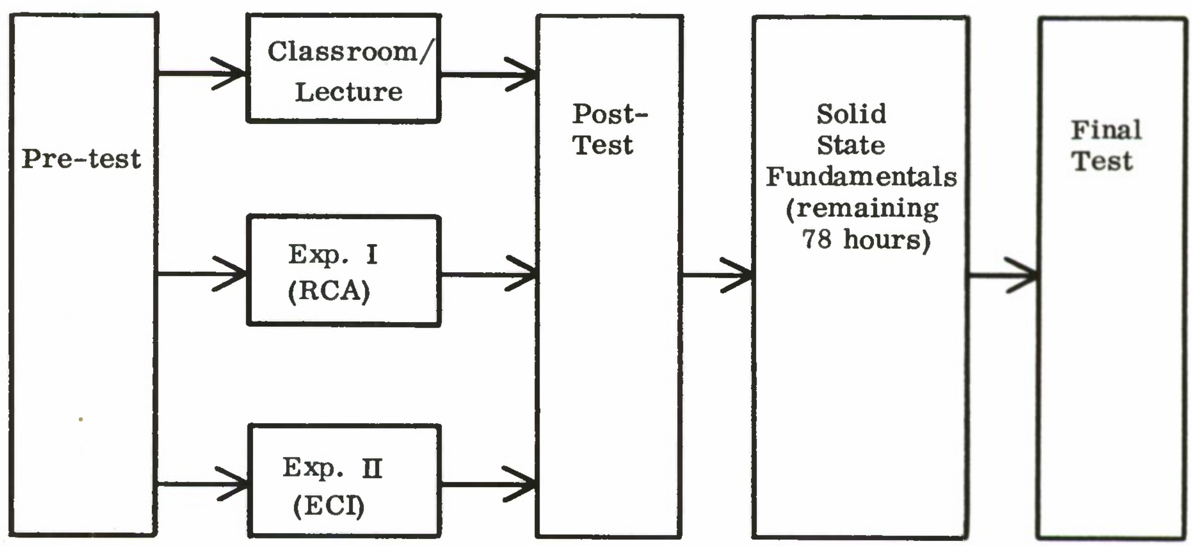


Figure 4. Experimental Design

[3] Edwards, A. L.; Experimental Design in Psychological Research; Holt, Rinehart and Winston, 1964, pp. 158-174

2. DESCRIPTION OF INSTRUCTIONAL MODES

Three methods of presentation or modes were compared by a controlled experiment in an operational setting. The control mode consisted of the first 24 hours of the normal course which was conducted by the Career Development Branch. The last 78 hours of the normal course were taught to all subjects in the usual way. Self-sufficient multi-media materials were developed as another presentation mode by RCA, described in detail earlier in this report. Existing materials from Air Force Extension Course Institute (ECI) Course Number 3032, Fundamentals of Solid State Devices, were selected as a third presentation mode. Chapters 1, 2, 3 and 4 of the first volume and Chapters 1 and 2 of the second volume of this course were selected.

A picture of the classroom used for the control group instruction and the last 78 hours of instruction is shown in Figure 5. A picture of the study room used by the Experimental Group II (ECI) is shown in Figure 6. Photographs of the Experimental Group I (RCA) instructional environment are included earlier in this report.

3. PLAN OF EVALUATION AND RESULTS

The evaluation of the instructional modes was based on the following five measures:

(1) The ratio gains between a pre-test and post-test.

(2) An item analysis of both the pre-test and post-test. Each test item was compared on the basis of whether students gained or lost in proficiency between pre-test and post-test.

(3) Attendance records, dropout records and total time for the experimental part of the course for all three modes.

(4) Students' impressions of the multi-media materials as expressed during structured interviews, and

(5) Final course grades, dropout records and attendance records of all subjects during the final 78 hours of common instruction.

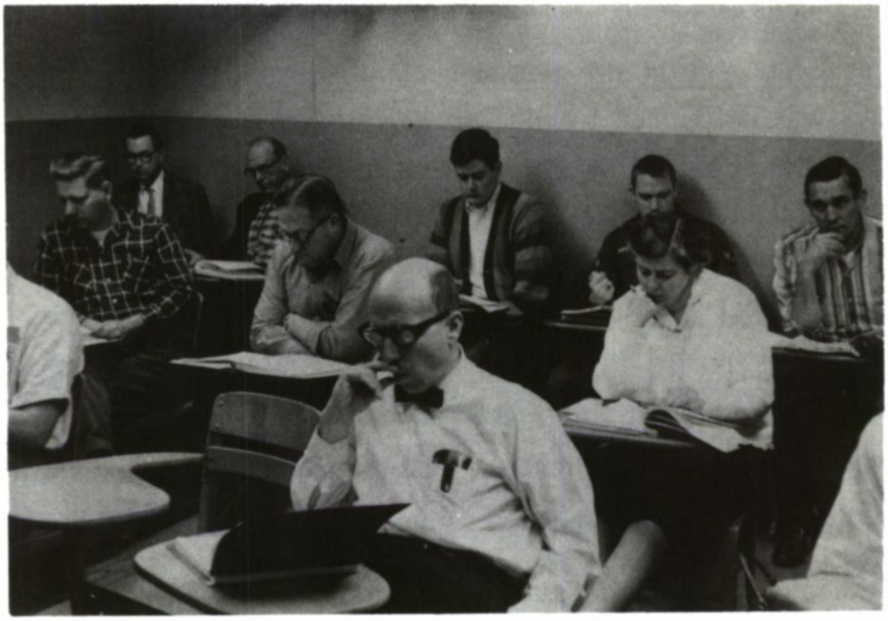


Figure 5. Control Group (Classroom) Environment

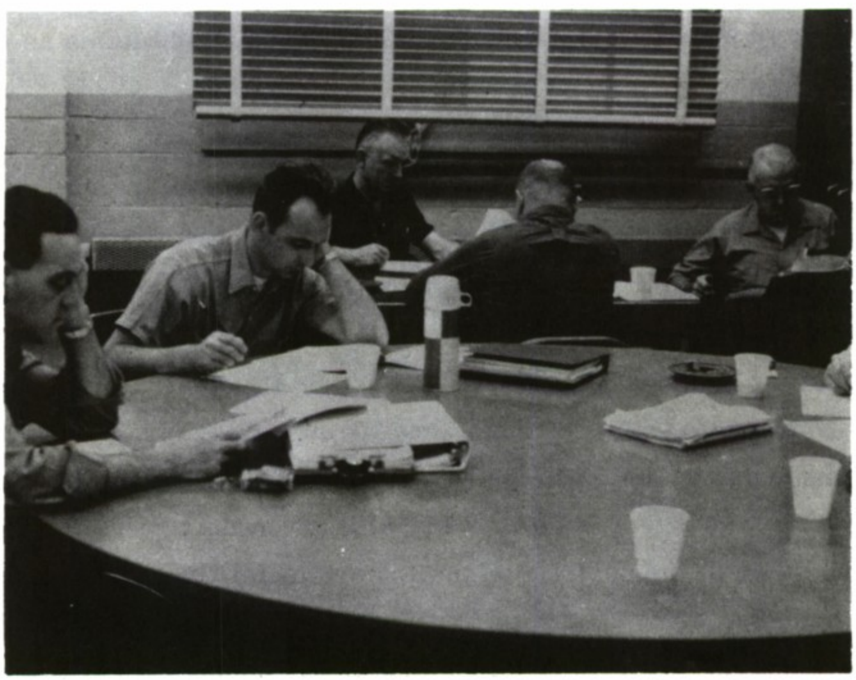


Figure 6. Experimental Group II (ECI) Environment

a. Experimental Comparison of the Three Modes of Instruction

The description of the pre-test and post-test. Both the pre-test and the post-test are based on the outline described above for the first 24 hours of the traditional course. The test contained 100 questions - the first 12 were on general semiconductor field, introductory; the next 15 questions, on electronic fundamentals, background reference; 25 questions, on semiconductor physics; 10 questions, on conduction, biasing, symbology, real components; 28 questions on amplifier behavior; and 10 questions, on applications and laboratory procedures. A copy of the pre-test is included in Appendix III together with a reference sheet showing the item correspondence between the two tests. Since the post-test items were very similiar to the pre-test items, a copy of the post-test is not included.

Both the conventional classroom instruction and the RCA multi-media self study materials were based on the same outline as the 100 item pre-test and post-test. These test items were compared with the ECI self study materials. This comparison indicated that five items on the pre-test and the corresponding five items on the post-test were not covered in the ECI materials. The pre-tests and the post-tests for all subjects were therefore scored on the basis of 100 items as well as on the basis of 95 items.

Subjects and formation of groups. The subjects for this experiment were Military and Civilian Personnel at Wright-Patterson AFB, Ohio. In general, they were technicians who needed training in transistors. Each potential subject was given the OTIS Self-Administering Test of Mental Ability, higher examination Form A. Since the majority of subjects could be superior adults, the test time was limited to 20 minutes. On the basis of the raw scores obtained on this test, three matched groups of subjects were obtained. By lot, these three groups were assigned to Control Group (conventional instruction), Experimental Group I (RCA instruction) or Experimental Group II (ECI self-study). All subjects were also given the pre-test prior to receiving any instruction. Two of the subjects in the Experimental Group I received very low scores on the pre-test. The scores of these subjects and their matches in the other two groups were eliminated from consideration in the experiment. This resulted in three matched groups of 12 each for experimental purposes. In order to ensure that the three groups were as nearly equal as possible an analysis of variance was calculated

on both the OTIS Raw Scores and the pre-test scores for the subjects in the three groups. These indicated no significant difference between the groups by either measure. It was assumed, therefore, that the three groups were equal. Results of these calculations are given in Table II and Table III (see Appendix IV for data).

TABLE II

Analysis of Variance of OTIS Raw Scores on Three Matched Groups

Source	SS	df	MS	F
Treatment	506.00	2	2.53	1.140*
Block	2,289.89	11		
Residual	48.90	22	2.22	
Total	2, 343.89	35		

*Not significant

TABLE III

Analysis of Variance of Pre-test Scores on Three Matched Groups

Source	SS	df	MS	F
Treatment	71.06	2	35.53	.150*
Block	741.56	11		
Residual	208.94	22	236.77	
Total	021.56	35		

*Not significant

Analysis of Results of the Three Groups: Analyses of variance and appropriate F tests were calculated on the basis of the scores obtained by the three groups for both the 100 item scores and the 95 item scores. Table V gives the results of an analysis of variance between the groups for the 100 item scores. This analysis showed that a significant difference existed somewhere in the results obtained from the three treatments (see Appendix IV for data).

TABLE IV

Mean Values for OTIS Raw Scores, Pre-test and Post-test Scores, and Ratio Gain Scores

	Groups (N=12 for each)		
	Control	Exp I (RCA)	Exp II (ECI)
OTIS raw scores	43.5	43.9	44.4
Pre-test scores (100 questions)	54.1	50.9	53.6
Post-test scores (100 questions)	81.1	76.9	67.8
Ratio gain scores (100 questions)	.580	.521	.308
Pre-test scores (95 questions)*	51.7	48.6	51.2
Post-test scores (95 questions)*	76.7	72.6	64.2
Ratio gain scores (95 questions)*	.582	.460	.300

*5 questions not covered in ECI materials deleted.

Mean Values of Obtained Scores: After the subjects had completed the experimental portion of their respective courses, they were given a post-test described above. Table IV gives the mean scores obtained by all groups for the pre-test and post-test as well as for the mean raw scores on the OTIS. Since an evaluation of the 100 item pre-test and post-test indicated that five of the items in each test were not directly covered in the ECI course, both tests were rescored with the five items deleted. Ratio gain scores were calculated for each subject for both the 100 item test scores and the 95 item scores. The ratio gain score was obtained by dividing the actual gains made by each subject by his possible gain between the pre-test and post-test scores. Table IV, also, gives the mean ratio gain scores obtained by all groups.

TABLE V

Analysis of Variance of Pre-test/Post-test Ratio Gain Scores for the Three Groups

Source	SS	df	MS	F
Treatment	.490	2	.245	8.45*
Block	.597	11		
Residual	.637	22	.029	
Total	1.724	35		

*Significant at .005 level

F tests were used instead of "T" tests to identify significant differences. F test's between the groups indicated that no significant difference existed between the Control Group and the Experimental Group I (RCA) However, a very significant difference existed between the Control Group and Experimental Group II (ECI). There was also a significant difference between the Experimental Group I (RCA) and the Experimental Group II (ECI). The results of these F tests are given in Tables VI, VII, and VIII.

TABLE VI

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Control Group and Experimental Group I (RCA)

Source	SS	df	MS	F
Treatment	.020	1	.02	.690*
Block	.446	11		
Residual	.316	11	.029	
Total	.782	23		

*No significant difference

TABLE VII

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Control Group and Experimental Group II (ECI)

Source	SS	df	MS	F
Treatment	.443	1	.443	18.46*
Block	.396	11		
Residual	.267	11	.024	
Total	1.106	23		

*Significant at .005 level

TABLE VIII

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Experimental Group I (RCA) and Experimental Group II (ECI)

Source	SS	df	MS	F
Treatment	.272	1	.272	8.00*
Block	.671	11		
Residual	.373	11	.034	
Total	1.316	23		

*Significant at .025 level

Since the evaluation of the pre-test and post-test indicated that five of the questions on the pre-test and post-test were not directly covered in the ECI course, these five questions were deleted from the total scores of the three groups and an analysis of variance was also accomplished. The results of this analysis of variance and F tests are given in Tables IX, X, XI and XII (see Appendix IV for data).

TABLE IX

Analysis of Variance Concerning Pre-test/ Post-test Ratio Gain scores for the Three Groups (5 questions not covered in ECI Materials Deleted)

Source	SS	df	MS	F
Treatment	.482	2	.241	8.607*
Block	.589	11		
Residual	.621	22	.028	
Total	1.632	35		

*Significant at .005 level

TABLE X

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Control Group and Experimental Group I (RCA) (5 questions not covered in ECI Materials Deleted)

Source	SS	df	MS	F
Treatment	.090	1	.090	3.33*
Block	.360	11		
Residual	.301	11	.027	
Total	.751	23		

*Not significant

TABLE XI

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Control Group and Experimental Group II (ECI) (5 questions not covered in ECI Materials Deleted)

Source	SS	df	MS	F
Treatment	.480	1	.480	16.00*
Block	.372	11		
Residual	.327	11	.030	
Total	.179	23		

*Significant at .005 level

TABLE XII

F Test Concerning Pre-test/Post-test Ratio Gain Scores for Experimental Group I (RCA) and Experimental Group II (ECI) (5 questions not covered in ECI Materials Deleted)

Source	SS	df	MS	F
Treatment	.153	1	.153	5.67*
Block	.643	11		
Residual	.294	11	.027	
Total	1.090	23		

*Significant at .05 level

The results of this analysis of variance and the three F tests were very similar to those of the first series of tests. On this second series of tests, however, the difference between the Experimental Group I (RCA), and Experimental Group II (ECI) was significant at the .05 level rather than the .025 level.

It can be concluded from those two series of tests (using the usual verbal (written) procedures for measuring the knowledge of electronic fundamentals) that there is no significant difference in effectiveness between the multi-media (RCA) program and the conventional classroom instructor program. Both programs are superior to the ECI program. The multi-media program did contain application exercises which included work on the RCA transistor trainer. The Control and ECI courses did not include any such laboratory application of the transistor fundamentals. It is reasonable to assume that the multi-media subjects learned several job-like behaviors in addition to the knowledge items measured by the traditional test. However, no measure was made of this additional learning.

b. Item Analysis of Test Questions on the Pre-test and Post-test

An item analysis was made of the matched test questions from the pre- and the post-test, together with the statement of possible gain, the actual gain and the ratio gain. The material is on file at the Behavioral Science Laboratory. This information should be of value to anyone wishing to utilize the RCA experimental multi-media course. It gives some inkling as to which areas the RCA was effective in presenting and which areas are weak (and in need of revision). It also gives a rough profile of what a similar

type of population to that used for this study can be expected to know before entering such a training program. Table XIII presents a breakdown of the number of questions in the pre-test and post-test showing gains, those having no possible gain, those showing a gain where a gain was possible, and those resulting in losses from the pre-test to the post-test. An examination of this table indicates that the Control (Classroom/Lecture) Group and the Experimental Group I, (RCA), are comparable as to the number of questions on which gains were made, 88 and 81, respectively. The Experimental Group II, (ECI), showed gains on 66 questions. The Control Group and Experimental Group I showed losses on 5 and 6 questions, respectively, while the Experimental Group II showed losses on 16 questions.

TABLE XIII

Number of Question Gains, No Gains, and Losses from Pre-test to Post-test (for Matched Groups)

	Control	Exp I (RCA)	Exp II (ECI)
Gain	88	81	66
No Possible Gain	2	3	3
No Gain	5	10	15
Loss	5	6	16
Total	100	100	100

It can be concluded as far as gains and losses in correct question response between equivalent items on the pre-test and post-test that both the instructor/classroom mode and the self-sufficient multi-media mode were more effective than the ECI mode. A slight difference in favor of the instructor/classroom mode over the multi-media is apparent from an examination of Table XIII. This may be only a chance difference, however.

c. Time and Attendance Records for the Control and Experimental Groups

Attendance records were maintained for both the Control Group and the Experimental Group II (ECI). The only way in which a student missing the Control Group instruction could make up an absence was by self-study. Both the Control and Experimental Group II students were scheduled two mornings a week, from 0800 to 1100. In case of absence, the Experimental Group II (ECI) students were encouraged to come in for a like time on some other day for make-up to study the extension course material.

A very complete record was made of the times utilized by the Experimental Group I (RCA). Most of these subjects spent considerably more time than the 24 hours allotted for classroom study. Many students remained overtime during scheduled class sessions, came in for extra sessions, and made up absences. This apparent high motivation is discussed further on page 32.

Appendix V includes a table depicting the date and time each subject spent attending the multi-media (RCA) program. The total time for each subject to complete the experimental program (approximately 24 hours of conventional course) is tallied as well as their pre and post-test scores, possible gain, the actual and the gain ratio. Also included is a reference to those interviewed at the completion of the multi-media program.

Each subject was asked to keep track of the time he spent in study or discussion outside of class. Table XIV is a synopsis of the attendance information for each of the groups.

TABLE XIV

Summary of Classroom and Study Time for All Three Groups

	Control	Exp I (RCA)	Exp II (ECI)
Number of subjects	12	12	12
Scheduled classroom time hours	24.0	24.0	24.0
Average actual classroom time (hours)	22.7	29.7	23.7
Average hours of outside (home) study	5.0*	1.4*	6.7*
Average hours of outside discussion	0.0	0.25*	0.9*
Average total hours of instruction or study	27.7*	31.4*	31.5*
Number of subjects who performed more than 24 hours classroom study	0 **	10	2
Number of subjects who indicated outside (home) study or discussion	9	5	6

*The amount of outside study and discussion was the amount reported by the students. Asterisked items should, therefore, only be considered as estimates.

**Since the Control group's classroom mode of instruction was scheduled lecture, it was impossible for this group to have more than 24 hours.

No conclusions as to group differences can be drawn from the time and attendance records of the three groups.

d. Magnetic Tape Interviews of Multi-Media Subjects

At the conclusion of the experimental portion of their course ten subjects in Experiment Group I (RCA) were interviewed. The purpose being to determine the subjects likes and dislikes concerning the course structure, media employed, approaches to specific topics, sense of accomplishment, and courses utilizing self-study techniques. To solicit frank and yet comprehensive comments on all areas of interest, fifteen questions were prepared to be asked during the interview. The list of questions and a summary of comments of each interviewed subject are included in Appendix VI.

e. Comparison of Control and Experimental Groups Based on Behaviors During Last 78 Hours of Solid State Fundamentals.

Analysis of scores obtained on final examination. After the subjects had completed the final 78 hours of instruction they were given a 100 question final examination. A copy of the final test is included in Appendix III. Due to dropouts and incompletes the number of matched triplets was reduced to six. The mean values for the control, multi-media, and the ECI groups were 82.0, 78.3 and 74.0, respectively. An analysis of variance was calculated on the basis of the scores obtained by the three groups. The result is given in Table XV. This analysis of variance indicated no significant difference existed among the three groups. (See Appendix VII for data).

TABLE XV

Analysis of Variance of Final Test
Scores for the Three Groups

Source	SS	df	MS	F
Treatment	192.45	2	96.23	.67*
Block	624.45	5		
Residual	1429.88	10	142.99	
Total	1249.78	17		

*Not significant

Completion and dropout data for last 78 hours of instruction. Tables XVI summarizes the number of completions, incompletes and dropouts for each group. Although no great differences are indicated, it should be noted that the RCA group had a greated percentage of on-time satisfactory completions.

TABLE XVI

Number of satisfactory on-time completions, satisfactory late completions, incompletes, and dropouts among experimental matched subjects.

	Control	RCA	ECI
No. subjects	12	12	12
No. satisfactory on-time completions	.8	11	8
No. of late completions	0	0	0
No. of incompletes	2	0	1
No. of dropouts	2	1	3

Attendance records during last 78 hours of instruction. The total number of hours attended by each subject in the matched groups is given in Appendix VIII. An examination of this record revealed no substantial difference among the groups after dropouts are eliminated.

f. Summary of Results of Various Measures

(1) The pre-test/post-test comparisons indicated that there was no significant difference between the self sufficient multi-media mode and the classroom instructor mode even though the instructor classroom subjects received somewhat higher ratio gains scores, on the average, than the multi-media subjects.

(2) An item analysis of pre-test, post-test gains and losses by question indicated approximately the same pattern.

(3) The multi-media group spent more hours in actual classroom study than the other groups but somewhat less time in out-of-class study and discussion. The total times for the multi-media and ECI groups were about the same. Both exceeded that of the control group.

(4) Structured interviews indicated that the multi-media subjects liked this mode of instruction better then conventional classroom/laboratory instruction previously attended.

(5) All three groups did equally well on the final examination. More multi-media students completed the training on time with fewer dropouts than the other groups.

SECTION V

DISCUSSION

There is statistically no significant difference between the instructional effectiveness of the experimental course over the classroom mode. It should be pointed out, however, that the instructor/classroom mode of instruction was the end product of several tryouts and modifications on the part of the instructor. This was the first extensive tryout of the self-sufficient multi-media mode. A revision of these materials on the basis of the pre-test/post-test item analysis would no doubt improve the effectiveness of the multi-media materials.

It is probable that the paper and pencil testing techniques used in the pre-test, post-test and final test are not sensitive enough and comprehensive enough to measure many of the important outcomes of the various modes of instruction. The amount of long range retention affected by the various modes of instruction was, also, neglected in this study.

The automated self-study mode does exhibit some valuable characteristics. The instruction is standardized. That is, the instruction received by one student is exactly the same as that received by another student and is not subject to the variable moods or motivation of an instructor or different instructors. Also, the best instructional talent can reach the widest audience by this method.

A very high degree of motivation was displayed by automated program subjects. This was determined by observation of student reaction during administration of the experimental course. Some students actually seemed to be "trapped" by the program and were observed to remain at the student position in excess of four hours with no more than 20 minutes total for breaks. Other students remarked that they "could not wait to get back to the program" during the lapse of time between one class session and the next. Part of this motivation could have been due to the novelty of the mode but it is felt that it was not all due to novelty.

To gather additional data for appraisal of the somewhat intangible aspects of the program the course administrator examined each student's training manual to determine

the extent and accuracy of individual response to program cues. A surprisingly high level of student response was evident in their manuals. It was initially hypothesized that some students would ignore completely or at best make only cursory written responses to self-test and evaluation material. This was not born out by examination of these materials. Without exception all students responded <u>and</u> with a high degree of accuracy.

An automated instructional program can ensure active participation by <u>all</u> students in contrast to the passive participation of some students even under application of the most dynamic of classroom procedures. Also, he may repeat or review any section of the course material at will.

An automated self-study program offers 100% availability (discounting for the moment any machine malfunctions) in that the student may pursue the course at any time he desires and is not dependent on the availability of a human instructor. This is a very important advantage for an installation such as Wright-Patterson where it is necessary to give mature individuals training while they are engaged in full time employment. Many times the training needed to meet mission requirements is not available at the time it is most urgently required. The training may be required by too few employees to justify a conventional class. When conventional training is available, it is sometimes impossible to release an employee at the time the class is scheduled. Unforeseen TDY and emergency leave may interfere with formal class attendance. If a self study course that is equally effective to formal classroom training is available, employees can be trained on schedules that meet the needs of each individual work situation. This study demonstrated that such materials can be developed.

A self-study course can reach the widest possible audience, even potential students at remote duty stations, especially if the material is programmed for media which is lightweight and easily transportable. The possible economical advantage of reducing or eliminating the expense of student transport to and support at a central training location is worthy of consideration.

A multi-media program is such that an individual cannot skim over it. He must complete each set before he can go to the next one. In the case of the lecture type instruction (control), if a student happens to be daydreaming he just misses the

instruction. It is also possible to skim over or read materials less carefully in the extension course.

Before the experiment there were some doubts about the adequacy of the program's self-contained procedural direction. It was somewhat questionable as to whether all students would be able to familiarize themselves with machine operation and with direction for transition from medium to medium. Only minimal directions were included within the course so as to reduce the distraction, and resultant discontinuity, from course material. These fears were proven groundless not only by direct observation, but also by the interview when questions were posed on this facet of the multi-media course.

Four main equipment oriented difficulties were, however, encountered in the experiment. The first three involve the Graflex Audio-graphic instructor:

(1) As in many slide projectors the machine operation is too slow. The program could be enlivened and effect increased continuity and interest if the slide change time were reduced.

(2) It is difficult to back up in the program and maintain sound/picture synchronism with this machine.

(3) Machine reliability is less than optimum. The machine complexity and tendency for periodic malfunction precludes its use without the presence of on-the-spot maintenance support. Admittedly the complexity is not beyond the capability of the average student to comprehend. Quite probably the majority of malfunctions could be corrected by him, however, this is a serious detriment to learning effectiveness when a malfunction creates a division of attention between program material and machine behavior.

(4) The fourth equipment difficulty was experienced with the RCA 601-T Transistor-Trainers. Such wide variations in experimental results from trainer to trainer were experienced as to seriously detract from their training effectiveness. The lack of repeatability from trainer to trainer is believed to be attributed to variations in tolerance of component parts. In addition some design improvement to effect reliability and facility for meter to circuit connections is desirable.

SECTION VI

CONCLUSIONS

1. It is feasible to develop multi-media self-study materials for the teaching of electronic solid-state fundamentals.

2. As measured by ratio gain scores and item analysis between pre-test/post-test scores, the multi-media instruction was about as effective as traditional classroom instruction for teaching electronic solid state fundamentals. The somewhat higher mean score for the classroom instruction subjects was not significant. Both of these modes were superior to the present Air Force extension course for presenting like materials.

3. The presentation of self-sufficient multi-media does not require a subject matter specialist. A classroom monitor was required to keep the equipment used in this experiment operational. This reduced the effectiveness of the self-sufficient aspects of the multi-media program. Such a monitor could however maintain the equipment for several subject matter presentations at the same time.

4. Observation indicated that multi-media students were more highly motivated by their media during instruction than either the classroom students or the extension course students.

SECTION VII

GUIDLINES FOR DEVELOPMENT OF FUTURE AUTOMATED SELF-INSTRUCTION PROGRAMS

The authors of the multi-media program used in this research gained several valuable insights which they believe should be considered in the development of future self-instructional multi-media programs whether for operational or research use. In the construction of any such program the greatest attention should be given to:

(1) selecting a medium which is within the capability of the intended audience to use and which is extremely reliable and flexible.

(2) exploiting the inherent motivational aspects of both the instructional material and the medium.

(3) maintaining the level of student activity at the highest attainable level throughout the course.

(4) building in a maximum degree of flexibility in program pacing so that faster students will not become bored and slower students will not become frustrated.

(5) inclusion of the maximum extent of student encouragement practicable, i.e. positive reinforcement. Let the student not only know that he is learning but also of what personal value this learning is to him.

(6) maintenance of continuity and student orientation throughout the course. Let the student know where he is, where he has been, and where he is going.

(7) inclusion of a sufficient degree of flexibility so that the student, studying at his own rate, will not suffer disorientation and discontinuity by his own study pattern, that is, where he breaks and resumes his program study.

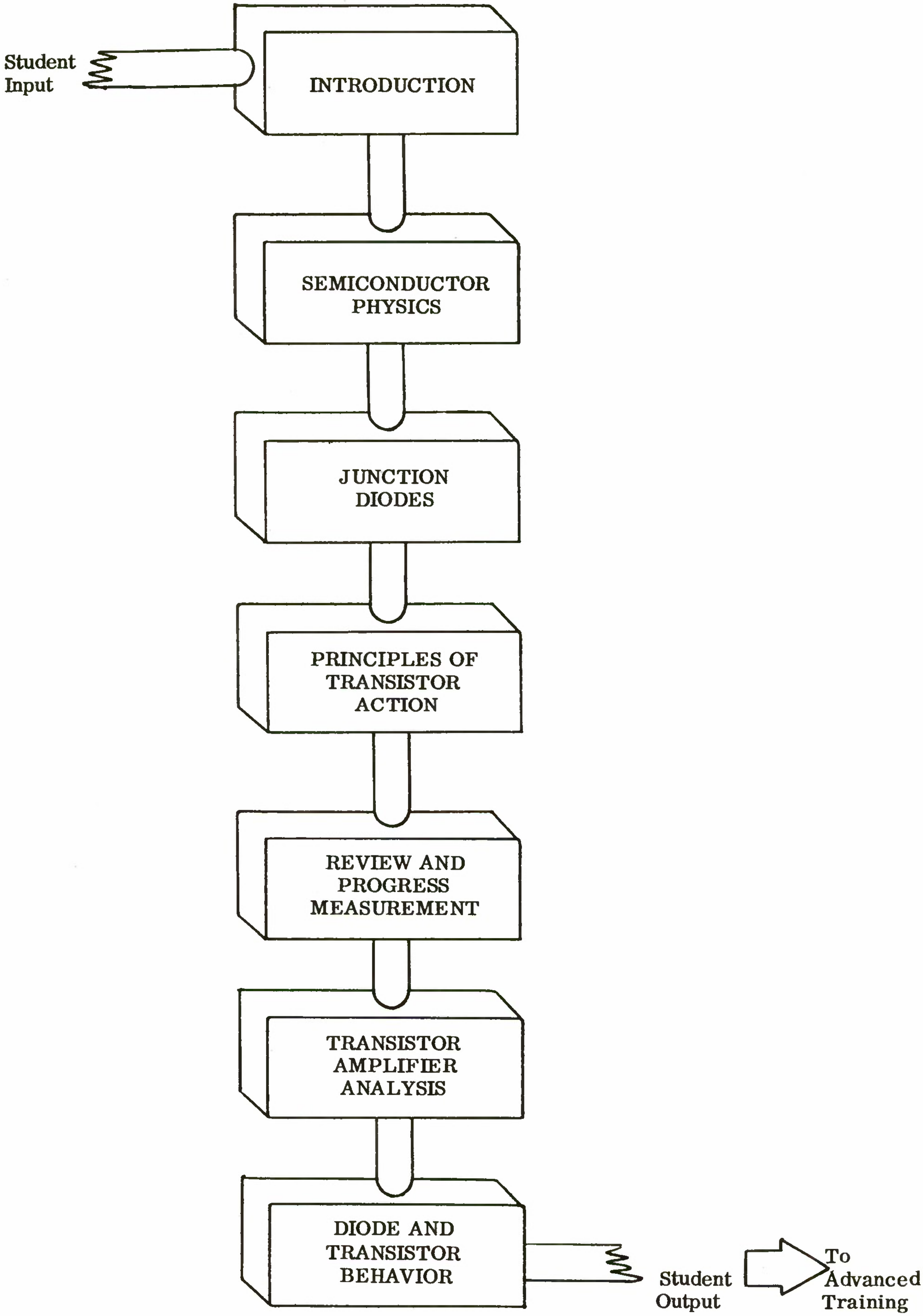
(8) inclusion of total course indices to facilitate the students review of any section desired without having to repeat whole sections only to refresh on certain finite concepts.

APPENDIX I

PRODUCTION FLOW DIAGRAM

FUNDAMENTALS OF TRANSISTORS

A MULTIMEDIA SELF-INSTRUCTIONAL COURSE


Student
Input
INTRODUCTION
SEMICONDUCTOR
PHYSICS
JUNCTION
DIODES
PRINCIPLES OF
TRANSISTOR
ACTION
REVIEW AND
PROGRESS
MEASUREMENT
TRANSISTOR
AMPLIFIER
ANALYSIS
DIODE AND
TRANSISTOR
BEHAVIOR
Student
Output
To
Advanced
Training

INTRODUCTION A

A-V and Written Direction

1. INITIAL IMPACT
   - Fanfare
   - Dynamic Shots (Missiles etc.)
   - Dialogue
   - Performing Personnel

2. COURSE INTRODUCTION
   - Title
   - Purpose
   - Advantages
   - Methods Used
   - Special Features
     - Flexibility
     - Repeatability
     - Self-Pacing
   - Sequencing

3. SEMICON APPLICATIONS
   - Aerospace
   - Computers
   - Production Control
   - Home Instruments
   - Shots of All of Above
   - Typical Components

4. HISTORY
   - Gallenium Crystal
   - Diode Detector
   - 1st Transistor 1948
     - Bell Labs./Inventors
   - Semicon/Tube Evolution

SEMICONDUCTOR PHYSICS B

A-V, Audio with Chart Supplement
Reference Test Reading Assgnmt.

1. STRUCTURE OF MATTER
    - Atomic Theory
    - States of Matter
    - Forms of Matter
    - Periodic Table
    - Terms & Definitions
    - Atomic Particles & Charge
    - Electrical Units
    - Valence

2. CONDUCTION & RESISTIVITY (PURE XTALS)
    - Free Electrons
    - Current vs. Temperature
    - Current vs. Specific Resistivity
    - Crystal Contamination Effects
    - Terms, Definitions & Examples
        - Conductors
        - Semiconductors
        - Insulators
    - Field Effects
        - Electrostatic
        - Magnetic
        - Photo

3. CRYSTAL STRUCTURE & BONDING
    - Chemical Activity & Valence
    - Crystal Structure
        - Covalent Bonding
        - Amorphous vs. Crystalline Materials
    - Electron Mobility/Availability

4. CURRENT CARRIERS & SEMICONDUCTOR PROCESSING
    - Doping & Xtal Structure
        - Impurities & Proportions
        - Current Carriers
    - N&P Type Semicon
        - Donors
        - Acceptors
    - Carriers
        - Charge
        - Polarity
        - Direction
        - Generation

JUNCTION DIODES C

Programmed Text,
A-V Supplement

1. THE PN JUNCTION
   - Definitions
   - Formation Process (Mfg.)
   - Typical Dimensions

2. JUNCTION EFFECTS (THEORY)
   - Hole-Electron Interchange
   - Depletion Zone (Barrier Effect)
   - Current Carriers & Flow
     - Internal
     - External
   - Effect of External Battery
     - Reverse Bias
       - Battery Polarity
       - Conduction Process
     - Forward Bias
       - Battery Polarity
       - Conduction Process
     - Rectification
   - Typical Junction Behavior
     - Volt-Amp. Curves
     - Temp. Effects
     - Breakdown
     - Majority & Minority Carriers

3. COMPONENT & SCHEMATIC FAMILIARIZATION
   - Typical Diodes (Actual Components)
   - Graphic Symbols
   - Characteristics & Parameters (Curves)
   - Typical Uses

PRINCIPLES OF TRANSISTOR ACTION — D

Cued Text

1. TRANSISTOR CONSTRUCTION
   - 3 Element, 2 Junction
   - Symbology
   - Mfg. Processes
   - Component Familiarization

2. CONDUCTION PROCESS
   - Bias Polarities
     - NPN, Forward & Reverse
     - PNP, Forward & Reverse
   - Current Relationships
     - Relative Magnitudes
     - Directions, (Internal & External)

3. TYPICAL APPLICATION & OPERATION
   - Operational Parameters (General)
     - Temp. Limits
     - Current Limits
     - Breakdown Effects
   - Shock & Vibration
   - Handling & Repair Consid.
   - Special Features
     - Heat Sinks
     - Thermal Barriers
     - Current & Power Limiting

4. 3 AMPLIFIER ARRANGEMENTS
   - Common Base, Common Emitter, Common Collector
     - Input/Output Circuits
     - Compared to V. T. 's
     - Bias Bats. & Polarities
       - 2 Bat.
       - Single Bat.
       - Special Circuits

REVIEW AND PROGRESS MEASUREMENT E

Sound Movie
Written Self Test

1. JELL CONCEPTS
   - Animated Movie
   - Live Shots
   - Audio Summation

2. CORRECT MISCONCEPTIONS
   - Comprehensive Self-Test
     - Definite Student Response
     - Progress Meas. Stnds.
   - Provide Remedial Instr. or Review
     - Direction to Specific Course Section

TRANSISTOR AMPLIFIER ANALYSIS F

Work Book

1. AMPLIFIER ARRANGEMENTS
   - CB, CE, CC
     - Input Circuits
     - Output Circuits

2. AMPLIFIER BEHAVIOR (3 CONFIGS.)
   - Current Relations
   - Voltage Phase Relations
   - Typical Resistance Ratios
   - Symbols & Computations
     - Alpha
     - Beta
     - Icbo etc.
     - Temp. Rise %Factor etc.
   - Gain Relations (Computed)
     - Current Gain
     - Power Gain
     - Voltage Gain
     - Impedance Gain
   - Typical Characteristics, 3 Amps (Chart)

3. PARAMETERS & CHARACTERISTIC CURVES
   - Typical Curves, Analyzed
     - Vbe vs. Ib
     - Vbe vs. Vce
     - Ic vs. Vce
   - Precautions & Operating Limits
     - Thermal Runaway
     - Icbo
     - Bias Stabilizing
     - Degeneration & Feedback

DIODE & TRANSISTOR G
BEHAVIOR

601-T Trainer
A-V Direction

1. EQUIPMENT INTRODUCTION
   - 601-T Trainer
   - WV-38A
   - WV-77E
   - Tools, etc.

2. PRACTICES & PRECAUTIONS
   - Equipment Set-Up
   - Energizing
   - Testing Practices
   - Meter Protection
   - Component Protection

3. EXPERIMENT DIRECTION
   - Junction Behavior (Diode)
     - Circuit Connection
     - Measurements
     - Data Collection
     - Operational Verification
   - Temp. Effects (Diode)
     - Same as Above
   - Transistor Behavior (2 Junction)
     - Circuit Connection
     - Measurements
     - Data Collection
     - Curve Construction
     - Results Verification
   - Environmental Effects
     - Temperature
     - Variable Voltages
     - Variable Currents
     - Results Verification

4. COURSE SUMMATION
   - Review
   - Self-Test
   - Remedial

5. FINAL EXAM.
   - Written
   - Oral
   - Practical
   - Evaluation
     - Students
     - Course

APPENDIX II

COURSE OUTLINE FOR 100 HOURS

FUNDAMENTALS OF TRANSISTORS AND SOLID STATE DEVICES

Presented Periodically
Under the Auspices of

CAREER DEVELOPMENT BRANCH
CIVILIAN PERSONNEL DIVISION
AERONAUTICAL SYSTEMS DIVISION
WRIGHT-PATTERSON AIR FORCE BASE, OHIO

by

Mr. Walter C. Laudig

COURSE OUTLINE

About 100 hrs.

FUNDAMENTALS OF TRANSISTORS AND SOLID STATE DEVICES

1.	Introduction, Registration and Student Books and Material Assignment		1/2 hr.
2.	Fundamental Theory of Transistors		9 hrs.
	a. Structure of Matter	1/2 hr.	
	b. Crystals, Donors, Acceptors and Holes	3 hrs.	
	c. PN Junctions	3 hrs.	
	d. Transistors, Manufacturing, Types and Applications	2-1/2 hrs.	
3.	Transistor Amplifier Fundamentals		9 hrs.
	a. Common Base, Common Emitter, Common Collector	1-1/2 hrs.	
	b. Methods of Bias	1 hr.	
	c. Symbols and Schematic Representation	1/2 hr.	
	d. Current Flow (electrons and holes)	2 hrs.	
	e. Reverse and Foreward bias currents	2 hrs.	
	f. Math Analysis of base lead and leakage currents	2 hrs.	
4.	Math Analysis of Transistors, Equivalent Circuits, Parameters and Characteristic Curves		6 hrs.
	a. Hybrid Parameters	2 hrs.	
	b. C Base, C Emitter, Common Collector	2 hrs.	
	c. Open and Short Circuit Parameters	2 hrs.	

5.	Bias and Temperature Stabilization		6 hrs.
	a. Reason for Stabilization and Effects of Non-Stabilization	1 hr.	
	b. Resistor Stabilization Methods	1 hr.	
	c. Thermistor Stabilization Circuits	1 hr.	
	d. Diode Stabilization Circuits	1 hr.	
	e. Transistorized Stabilization Circuits	1 hr.	
	f. Voltage Stabilization	1 hr.	
6.	Transistor Analysis and Comparison using Characteristic Curves and Charts		6 hrs.
	a. Transistor Equations and Chart Application	2 hrs.	
	b. Comparison of various transistors by equation, chart and curves	2 hrs.	
	c. Various types of parameters, Alfa and Beta gain, input and output resistance, frequency cut-off and cause	2 hrs.	
7.	Audio Amplifiers		9 hrs.
	a. Introduction to small signal and power types	1 hr.	
	b. Preamplifiers	1 hr.	
	c. Coupling techniques, RC, transformer, and valuable resistors as applied to volume controls	1 hr.	
	d. Phase inverters and driver stages	1 hr.	
	e. Power Amplifiers, and design example	1 hr.	
	f. Push-pull and Complimentary Stages	1 hr.	
	g. Compound Connected Amplifiers	1 hr.	
	h. Bridge Connected Circuits	1 hr.	
	i. Review and Oral student examination	1 hr.	

8.	Tuned Amplifiers		<u>4 hrs.</u>
	a. Coupling networks and impedance matching methods	2 hrs.	
	b. Neutralization and unilateralization	1 hr.	
	c. Automatic gain control	1 hr.	
9.	Wide Band Amplifiers and Oscillators		<u>9-1/2 hrs.</u>
	a. Video Amplifiers, low and high frequency compensation	1 hr.	
	b. Hartley, Colpitts, Crystal, election coupled, Wien bridge, phase shift oscillators	2-1/2 hrs.	
	c. Circuit tracing of all above oscillators	2 hrs.	
	d. Resonant feedback oscillators	1 hr.	
	e. Non-resonant feedback oscillators	1 hr.	
	f. Multivibrators, free running, monostable, bi-stable, triggered and syncronized	2 hrs.	
10.	Pulse and Switching Circuits		<u>4 hrs.</u>
	a. Theory and application	1 hr.	
	b. Time constants and effects	1 hr.	
	c. Wave shaping circuits	1 hr.	
	d. Math analysis of these circuits	1 hr.	
11.	Modulation, Mixing and Demodulation		<u>2 hrs.</u>
	a. FM and AM	1 hr.	
	b. Detectors	1 hr.	

12. Speoial Solid State Devices — 2 hrs.

- a. Unijunotion — 1/2 hr.
- b. Tunnel Diode — 1/2 hr.
- c. Zever Diode — 1/2 hr.
- d. Silioon Controlled Rectifier — 1/2 hr.

13. Transistor Films. 7 Seotions with disoussion period — 3 hrs.

14. Student Work-Shop with RCA Trainer 601-T — 30 hrs.

- a. PN Junotions.
- b. Bias and Stabilizations.
- c. Audio and RF Amplifiers.
- d. Power, Voltage and Current Gain.
- e. Plotting Characteristio Curves.
- f. Converter and IF Stages.
- g. Use of Meters, Soope and Signal Generators.
- h. Analysis and Alinement of Superhetrodyne Receiver.
- i. Multivibrators.
- j. Analysis of Transistor funotion in Common base, Common Emitter and Common Collector Configuration.

100 hrs.

Aids Used

TM - 11-690 Transistor Fund

Films - Transistor Theory and Application

RCA Demonstrator 601-T

Miscellaneous Veotor Board Circuits when applicable.

APPENDIX III

PRE-TEST/POST-TEST INFORMATION

AND

FINAL TEST

Contents:

(1) The Pre-test with page references by question to Extension Course Institute Course 3032 <u>Fundamentals of Solid State Devices</u> Vol. 1 and Vol. 2 indicating coverage of question material.

(2) Cross reference sheet equating the Pre-test and the Post-test. The Post-test was administered at the end of the experimental treatments after approximately 24 hours of scheduled instruction (since the Post-test items were very similar to the Pre-test items, a copy of the Post-test is not included).

(3) The Final Test. This test was administered to the subjects upon completion of the total course after 102 hours of scheduled instruction.

PRE-TEST *

FUNDAMENTALS OF TRANSISTORS

EXAMINATION

1. Transistors function as valves in electronic circuit applications. They are _______________ control devices.
(ECI Course 3032, Vol 1, pg 65, 2nd col.)
a. voltage
b. reactance
c. current
d. capacitance

2. The name "Transistor" derives from their ability to effect a:
(ECI Course 3032, Vol 1, pg 75)
a. transfer of resistance
b. transition from vacuum tubes to semiconductors
c. transformation of voltages
d. transitory medium from holes to electrons

3. Two principle advantages of transistors over electron tubes are:
(ECI Course 3032, Vol 1, pgs 4, 5)
a. greater power handling capability and freedom from temperature effects
b. ease of manufacture and economy of materials
c. low cost and standardization of characteristics
d. higher power efficiency and ruggedness

4. Transistors and other semiconductor devices are especially adaptable to the _______________ of electronic equipment.
(ECI Course 3032, Vol 1, pgs 3, 4, 5)
a. stabilizing
b. miniaturization
c. standardizing
d. manufacturing

5. Electronic components for use in transistor circuits are usually:
(ECI Course 3032, Vol 1, pg 7)
a. much smaller with higher voltage ratings
b. much larger with smaller voltage ratings
c. much smaller with lower voltage ratings
d. much larger and higher voltage ratings

6. The first application of the semiconductor diode principle was in the:
(ECI Course 3032, Vol 1, pg 2, 1st col.)
a. rotary spark gap transmitter
b. the "Gallenium crystal-cat whisker" radio receiver
c. microphone
d. telephone

* Annotated with page references by question to Extension Course Institute Course 3032 Fundamentals of Solid State Devices Volumes 1 and 2.

7. Point contact diodes were first used to replace vacuum tube diodes in radar equipment because of:
(ECI Course 3032, Vol 1, pg 2, 1st col.)
   a. their small size and high frequency characteristics
   b. the shortage of tubes during World War II
   c. the discovery of Germanium
   d. their high current characteristics

8. The first practical point contact transistor was announced in:
(ECI Course 3032, Vol 1, pg 2, 1st col.)
   a. 1879   b. 1932   c. 1948   d. 1945

9. Transistors can be used to accomplish the functions of ______________ in electronic equipment.
(ECI Course 3032, Vol 1, pg 3, 1st col.)
   a. amplification and oscillation
   b. timing and switching
   c. modulation and demodulation
   d. all of above

10. As compared to the vacuum tube, the noise level of a transistor is ______________ and is ______________ proportional to frequency.
(ECI Course 3032, Vol 1, pg 5, last 5 lines; pg 6, top)
   a. lower and is directly
   b. lower and is inversely
   c. higher and is inversely
   d. higher and is directly

11. The basic characteristics of the elements, such as number of orbital electrons, number or orbits and chemical activity can be obtained by:
(ECI Course 3032, Vol 1, pg 12, 2nd col.)
   a. referring to a chart called a periodic table
   b. referring to a table of atomic weights of the isotopes
   c. referring to tables of specific resistivity of the elements
   d. x-ray difraction measurement techniques only

12. The principle disadvantage of the junction transistor as compared to the point contact transistor is:
(ECI Course 3032, Vol 1, pg 77)
   a. lower power handling capability
   b. lower frequency limitations
   c. greater size and weight
   d. higher signal to noise ratio at high frequencies

QUESTIONS 13-27 ARE ON FUNDAMENTALS OF ELECTRONICS

(THIS MATERIAL IS NOT INCLUDED IN THE ECI COURSE)

13. Ohm's law states that the current in a resistive circuit is:

a. directly proportional to the voltage applied and to the resistance in the circuit
b. inversely proportional to the voltage applied and to the resistance in the circuit
c. directly proportional to the resistance in the circuit without regard to the voltage
d. directly proportional to the voltage applied and inversely proportional to the resistance in the circuit

14. Kirchoff's voltage law states that the algebraic sum of the voltages drops in a closed series circuit is equal to:

a. zero
b. the arithmetic sum
c. the source voltage
d. none of above

15. The reactance of an inductor may be expressed as:

a. $(2 \pi FL)^2$ b. $\frac{1}{2 \pi FL}$ c. $\frac{XL}{2 \pi F}$ d. $2 \pi FL$

16. Frequency distortion in an amplifier occurs when:

a. all frequencies are amplified equally
b. some frequencies are amplified more than others
c. the output load is resistive
d. the input circuit is resistive

17. A cathode follower is an amplifier:

a. that has a high voltage gain
b. that has a voltage gain of unity
c. that has a voltage gain of less than unity
d. that has no practical use

18. One useful function of the diode vacuum tube is:

a. amplification
b. filtering
c. rectification
d. regeneration

19. One means of obtaining self-bias in a vacuum tube amplifier is through the use of a resistor in the:

a. plate circuit
b. screen circuit
c. cathode circuit
d. power supply

20. The variations in voltage produced by a simple a-c generator throughout one cycle is usually represented by:

a. a sawtooth curve
b. a sine curve
c. a square wave
d. a series of vertical lines

21. The basic unit of electrical quantity is the ______________ and is equal to the combined charge of 6.28×10^{18} electrons.

a. coulomb
b. ohm
c. farad
d. fermi

22. If the resistance of a conductor increases as its temperature is increased, it is said to have a ______________ temperature coefficient of resistance.

a. negative
b. positive
c. neutral
d. variable

23. The mu of a vacuum tube is a measure of:

a. the static plate current required for minimum distortion
b. the equivalent internal resistance of the tube
c. the tube's inherent noise figure
d. the effectiveness of the grid voltage in controlling the plate current

24. Diode detectors exhibit the property of:

a. low distortion and gain less than unity
b. overloading rather easily
c. developing a filtered AVC voltage
d. distortion on small signals

25. Grounded-grid vacuum tube amplifiers are used in high frequency circuits to:

a. reduce the degenerative effect of the interelectrode capacitance
b. reduce the circuit shock hazard
c. eliminate one tuned circuit
d. drain off the space charge

26. When measuring the voltages in an electronic circuit a high impedance voltmeter (e.g., a VTVM) is recommended so as to:

a. reduce the shock hazard
b. increase measurement accuracy by increasing circuit loading
c. increase measurement accuracy by reducing the circuit loading
d. allow a mid-scale meter deflection for increased measurement accuracy

27. The resistance of a resistor is usually not affected by:

a. its dimensions
b. the resistance of other components in the circuit
c. its temperature
d. its composition

28. The smallest particle of an element retaining the identity of the element is the:
(ECI Course 3032, Vol 1, implied on pg 13)
a. proton b. electron c. molecule d. atom

29. The term ______________ is used to describe the ability of an element to enter into chemical combination.
(ECI Course 3032, Vol 1, implied on pg 23)
a. valence c. atomic number
b. atomic weight d. energy level

30. Germanium or silicon which is processed for use in transistors must be in the ______________ form.
(ECI Course 3032, Vol 1, implied on pgs 16, 17, 23)
a. cubic c. polycrystalline
b. cylindrical d. single crystal

31. The nucleus of an atom:
(ECI Course 3032, Vol 1 - General Prerequisite Information)
a. is never positive
b. has a charge of 1.6×10^{-10} coulomb
c. contains protons and neutrons
d. rotates around the protons

32. The valence electrons of an atom are:
(ECI Course 3032, Vol 1, pg 21)
a. those most loosely held by the nucleus
b. closest to the nucleus
c. in the forbidden band
d. are those most tightly held by the nucleus

33. A crystal lattice:
(ECI Course 3032, Vol 1, pg 24)
a. is a transparent substance
b. exists only in germanium
c. is the regular array of atoms in a pure solid
d. exists only in carbon

34. Semiconductor materials like germanium or silicon are held together:
(ECI Course 3032, Vol 1, pg 24)
a. by bonds between electrons and nucleus
b. by covalent bonds between adjacent atoms
c. by the electrostatic attraction of the semiconductor atoms for each other
d. by the impurity ions

35. A good conductor is a material that:
(ECI Course 3032, Vol 1, pg 21)
a. does not change characteristics with temperature
b. has a low atomic weight
c. is chemically inert
d. has a large number of free electrons

36. An atom which has gained an extra electron in its outer orbit is called a(n):
(ECI Course 3032, Vol 1, pgs 41, 42, 43)
a. isotope
b. positive ion
c. negatron
d. negative ion

37. Holes are the principle current carriers in:
(ECI Course 3032, Vol 1, pgs 29, 30)
a. undoped germanium
b. N-type germanium
c. P-type germanium
d. the depletion region

38. Holes travel:
(ECI Course 3032, Vol 1, pg 27)
a. as fast as electrons
b. in the same direction as electrons
c. only in N-type germanium
d. in the direction opposite to that of electrons

39. Minority carriers may be:
(ECI Course 3032, Vol 1, pg 27)
a. holes in P-type semiconductors
b. electrons in N-type material
c. holes in N-type semiconductors
d. produced only by doping

40. An important characteristic of semiconductors is that their:
(ECI Course 3032, Vol 1, pg 14)
a. conductivity goes down as temperature goes up
b. resistance decreases as temperature increases
c. conductivity is independent of temperature
d. resistance becomes zero at obsolute zero temperature

41. Elements having 3 electrons in their outer orbits:
(ECI Course 3032, Vol 1, pg 27)
a. are not used for transistor manufacture
b. purify impure germanium
c. are only used in place of arsenic
d. produce P-type semiconductors

42. More power is dissipated in a semiconductor diode under application of either forward or reverse bias when:
(ECI Course 3032, Vol 1, pgs 51-77)
a. the temperature of the diode is increased
b. the temperature of the diode is decreased
c. the voltage across the diode is decreased
d. the internal resistance is increased

43. In the external circuit of a semiconductor device, current is carried by:
(ECI Course 3032, Vol 1, pgs 63-66)
a. holes
b. both holes and electrons
c. electrons
d. positive or negative ions

44. The action of binding the valence rings together is known as the formation of:
(ECI Course 3032, Vol 1, pg 23)
a. covalent bonds
b. pentavalent bonds
c. trivalent bonds
d. "Series E" bonds

45. When an impurity atom having a valence of +5 is added to germanium:
(ECI Course 3032, Vol 1, pg 28)
a. it changes to a liquid
b. P-type semiconductor is formed
c. there is no change
d. N-type semiconductor is formed

46. Germanium in its pure form is:
(ECI Course 3032, Vol 1, pgs 12, 13)
a. a conductor
b. a semiconductor
c. a transistor
d. an insulator

47. The hole is the means of conduction within a:
(ECI Course 3032, Vol 1, pgs 29, 30)
a. pentavalent semiconductor
b. molecule
c. P-type semiconductor
d. N-type semiconductor

48. What type of energy is most apt to cause destruction to semiconductor devices?
(ECI Course 3032, Vol 1, pg 50)
a. light
b. sound
c. AC voltages
d. heat

49. An experiment which involves rotation of a body, which has been statically charged positive, past a compass needle supports the concept that:
(NOT IN ECI MATERIALS)
a. holes in motion produce electric current
b. motion nullifies static charges
c. motion causes an increase in charge
d. magnetic compasses are unreliable

50. The channeling of holes in P-type semiconductor material by an external electric field can be detected by:
(ECI Course 3032, Vol 1, pg 77)
a. examinations with a microscope
b. measuring the difference in hole transit time
c. measuring the temperature change
d. measuring the voltage drop

51. When an electron is torn away from a pair bond in the crystal lattice leaving a vacancy behind this process is called:
(ECI Course 3032, Vol 1, pg 28)
a. hole-electron pair recombination
b. hole-electron pair generation
c. electron-hole acceleration
d. depletion zone expansion

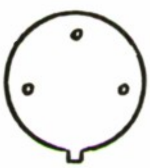
52. The beta rating of a transistor is most applicable in computing gain in the: (ECI Course 3032, Vol 1, pg 68)
    a. emitter-follower circuit
    b. common-collector circuit
    c. common-base circuit
    d. common-emitter circuit

53. The potential which exists at the junction of N and P type semiconductors is called the:
    (ECI Course 3032, Vol 1, pg 42)
    a. potential high voltage region
    b. reverse bias potential
    c. forward bias potential
    d. potential gradient or potential energy barrier

54. The process of manufacturing the P-N junction involves: (ECI Course 3032, Vol 1, pg 36)
    a. ultra fine machining of two surfaces to be joined
    b. pressure impregnation of solid semiconductor material
    c. zone refining and alternate doping of melted semiconductor material
    d. the joining of germanium and silicon

55. The arrow on the symbol for a transistor: (ECI Course 3032, Vol 1, pg 63)
    a. identifies the collector and denotes direction of electron flow
    b. identifies the emitter and denotes direction of electron flow
    c. identifies the collector and denotes direction of hole flow
    d. identifies the emitter and denotes direction of hole flow

56. Reading clockwise from the key tab, identify the elements on the accompanying transistor base drawing:
    (ECI Course 3032, Vol 1, pg 76)
    a. emitter, collector, base
    b. emitter, base, collector
    c. base, emitter, collector
    d. base, collector, emitter



57. To prevent damage to transistors when removing and replacing in a circuit: (NOT IN ECI MATERIALS)
    a. it should only be done at room temperature
    b. the circuit should always be de-energized first
    c. the collector should always be grounded first
    d. leads should be clipped rather than unsoldered

58. For forward bias in the P-N junction:
(ECI Course 3032, Vol 1, pg 53)
a. the negative battery terminal is connected to the P material
b. the positive battery terminal is connected to the N material
c. the positive battery terminal is connected to the P material
d. the negative battery terminal is connected to the junction

59. Forward bias applied to a P-N junction:
(ECI Course 3032, Vol 1, pg 52)
a. changes the semiconductor to a higher resistivity
b. increases the resistance to current flow
c. has a net charge of +5
d. decreases the resistance to current flow

60. The collector of a transistor is similar to:
(ECI Course 3032, Vol 1, pg 60)
a. the plate of a vacuum tube
b. the grid of a vacuum tube
c. the cathode of a vacuum tube
d. the outer shell of a metal vacuum tube

61. The P-N junction is capable of:
(ECI Course 3032, Vol 1, pg 39)
a. amplification
b. rectification
c. replacing a pentode
d. large power output

62. A short electron transit time through the base region:
(ECI Course 3032, Vol 1, pgs 47, 48, 77)
a. usually provides a higher frequency cut-off
b. creates higher potential barriers
c. provides a higher break down voltage
d. reduces the amplification capabilities of the transistor

63. The method of operating a transistor similar to that of a grid input vacuum tube circuit is called a:
(ECI Course 3032, Vol 1, pg 61)
a. common or grounded base
b. common or grounded emitter
c. common or grounded collector
d. normal base load connection

64. The current gain in a grounded emitter circuit is:
(ECI Course 3032, Vol 1, pg 68)
a. less than unity
b. equal to unity
c. zero
d. greater than unity

65. Current gain in the common base amplifier is:
(ECI Course 3032, Vol 1, pg 67)
a. called beta and is always less than unity
b. called beta and is always greater than unity
c. called alpha and is always less than unity
d. called alpha and is always greater than unity

66. The input resistance as compared to the output resistance of a grounded emitter amplifier is:
(ECI Course 3032, Vol 2, pg 20)
a. smaller
b. greater
c. the same
d. the same as electron tube amplifiers

67. Leakage current in a transistor is identified by the term:
(ECI Course 3032, Vol 2, pg 27)
a. I_c b. I_e c. I_{cbo} d. I_b

68. Excessive leakage current in a transistor can cause:
(ECI Course 3032, Vol 2, pgs 27, 28)
a. other components in the circuit to open
b. thermal runaway
c. increased gain
d. little or no effect

69. Leakage current is:
(ECI Course 3032, Vol 2, pg 27)
a. caused by majority carriers
b. caused by minority carriers and is in the same direction as the majority carriers
c. caused by improper transistor connection
d. caused by minority carriers and is opposite to the direction of majority carriers

70. The detrimental effects of positive feedback in the common-emitter circuit can be counteracted by:
(ECI Course 3032, Vol 2, pg 28)
a. increasing the operating temperature of the transistor
b. employing more extensive bias stabilization
c. increasing positive feedback
d. employing a heat sink

71. Current flow through a reverse biased diode is:
(ECI Course 3032, Vol 1, pg 77)
a. insensitive to changes in temperature
b. limited only by external circuit resistance
c. limited to that provided by thermally released minority carriers
d. dependent only upon applied voltage

72. Carriers crossing the junction of a reverse biased diode are:
(ECI Course 3032, Vol 1, pg 43)
a. holes from the P zone
b. majority carriers from both zones
c. electrons from the N zone
d. electrons from the P zone and holes from the N zone

73. For proper operation, the emitter-base junction of a transistor amplifier is always:
(ECI Course 3032, Vol 1, pgs 60, 61)
a. reverse biased
b. forward biased in PNP transistors only
c. forward biased
d. reverse biased in the PNP transistor only

74. In amplifier service, the collector terminal of a NPN transistor is:
(ECI Course 3032, Vol 1, pgs 60, 61)
a. left open
b. shorted to the base
c. made positive with respect to the base
d. made negative with respect to the base

75. The schematic symbols for transistors show:
(ECI Course 3032, Vol 1, pg 58)
a. the emitter arrow leaving the base for the NPN and entering for the PNP
b. the emitter arrow entering the base for the NPN and leaving for the PNP
c. the base of the NPN as an arrow entering the collector
d. the base of the PNP as an arrow entering the collector

76. In amplifier service, the base of a PNP transistor is:
(ECI Course 3032, Vol 1, pgs 60, 61)
a. made positive with respect to the emitter
b. made negative with respect to the emitter
c. made negative with respect to the collector
d. operated at the same d-c potential as the emitter

77. In the CB circuit, the current flowing in the collector circuit when the emitter terminal is disconnected is:
(ECI Course 3032, Vol 2, pg 27)
a. zero
b. very dependent upon collector voltage
c. decreases if the collector battery is reversed
d. equal to collector junction leakage current

78. Neglecting leakage current, if 10 ma flows into the emitter of a transistor whose alpha is 0.99 the base current equals:
(ECI Course 3032, Vol 1, pg 68)
a. 10 ma b. 0.99 ma c. 100 microamperes d. 9.9 ma

79. The beta of a transistor whose alpha is 0.985 is:
(ECI Course 3032, Vol 1, pg 68)
a. 65.7 b. 6.57 c. 98.5 d. 150

80. A PNP transistor is connected as a CE amplifier. If the instantaneous base voltage swings more positive, the:
(ECI Course 3032, Vol 2, pg 20)
a. collector voltage swings more negative
b. collector voltage becomes less negative
c. forward bias applied to the emitter junction increases
d. collector current increases

81. A transistor has a collector junction leakage current of 5 microamperes and an alpha of 0.99. If this transistor is placed in a CE circuit its approximate leakage current will be:
(ECI Course 3032, Vol 2, pg 27)
a. 5 microamperes b. 0.5 ma c. 50 microamperes d. 50 ma

82. The rate of electron-hole pair recombination at the transistor junction is affected by:
(ECI Course 3032, Vol 1, pgs 51-54)
a. bias applied
b. doping density
c. temperature
d. all of the above

83. When the transistor is made, high values of alpha are obtained by:
(ECI Course 3032, Vol 1, pg 77)
a. making the base region as thick as possible
b. decreasing the thickness of the collector region
c. making the base region as thin as possible
d. doping the emitter zone lightly

84. The voltage gain of the CB amplifier is:
(ECI Course 3032, Vol 2, pg 20)
a. always less than one
b. equal to beta times the load resistance
c. approximately equal to the ratio of the load resistance to the input resistance
d. increases as the load resistance is made smaller

85. The CC circuit provides:
(ECI Course 3032, Vol 2, pg 20)
a. a current gain lower than one
b. 180-degree signal inversion
c. high voltage gain
d. a voltage gain less than unity

86. The CC transistor circuit compares closely to the vacuum tube:
(ECI Course 3032, Vol 1, pg 61)
a. cathode follower circuit
b. grounded grid amplifier circuit
c. class A amplifier circuit
d. phase splitter circuit

87. The relationship between the input currents and the output voltage and current characteristics of a specific transistor are usually expressed by:
(ECI Course 3032, Vol 1, pg 68)
a. a simple equation
b. a set of curves which plot V_{ce} against I_c with various constant values of I_b or V_e
c. a set of curves which plot V_b against I_b
d. a set of curves which plot I_{cbo} against temperature

88. When a volt-ampere curve is made by varying the base current, and observing the resultant collector current, the:
(ECI Course 3032, Vol 1, pg 65)
a. collector current is usually plotted vertically
b. base current is the dependent variable
c. collector current is the independent variable
d. base current is plotted vertically

89. The larger a resistor is, the:
(Prerequisite information, or simple deduction)
a. closer its volt-ampere curve lies to the current axis
b. closer its volt-ampere curve lies to the voltage axis
c. the farther its curve is from the voltage axis
d. more nonlinear its volt-ampere curve becomes

90. The grown junction transistor is not applicable for use at very high frequencies because:
(ECI Course 3032, Vol 1, pg 77)
a. of its higher resistance
b. of its thermal limitations
c. high lead capacity
d. of the transit time of the current carriers in traversing the base region

91. The action of a zener diode in a shunt regulator is to keep the:
(ECI Course 3032, Vol 1, pg 87)
a. voltage across the series resistance constant
b. load voltage constant
c. current in the series resistance constant if the supply voltage varies
d. load current constant if load resistance changes

92. When using a single battery to obtain proper biases for a common-emitter circuit, the emitter-base bias is obtained:
(ECI Course 3032, Vol 2, pgs 29-32)
a. by a voltage divider across the battery
b. directly from the battery
c. by way of the internal resistance emitter-to base
d. by way of the internal resistance collector-to-emitter

93. What is the single most important factor to be considered in the application of a power transistor?
(ECI Course 3032, Vol 1, pg 77)
a. impedance matching
b. mounting
c. heat dissipation
d. output resistance

94. What is the main advantage of using a transistor as a phonograph pre-amplifier?
(By deduction)
a. no microphonics
b. better stability
c. increased sensitivity
d. no equalization required

95. What metal is most widely used in miniaturized capacitors?
(Prerequisite)
a. aluminum b. tantalum c. zinc d. cobalt

96. A _______________ _______________ transistor amplifier would be most appropriate for matching the input impedance of a 72 ohm transmission line.
(ECI Course 3032, Vol 2, pgs 20-23)
a. common collector
b. common emitter
c. common base
d. push-pull

97. The transistor circuit most appropriate for matching the output impedance of a low Z dynamic microphone would be the:
(ECI Course 3032, Vol 2, pgs 20-23)
a. common emitter
b. common collector
c. zener regulator
d. common base

98. The set-up necessary to obtain a partial current-voltage characteristic curve for a PNP transistor emitter-base junction consists of:
(NOT IN ECI MATERIALS)
   a. a sensitive milliameter connected in series with the base lead, a VTVM in series with the collector lead and the emitter left open
   b. A VTVM connected in series with the base lead, a sensitive milliameter across the emitter-base junction and the collector left open
   c. a sensitive milliameter in series with the base lead, a VTVM across the emitter-base junction and the collector left open
   d. a sensitive milliameter in series with the collector lead, a VTVM across the emitter load resistor and the base left open

99. The set-up necessary to observe the effect on I_c by varying I_b (or V_{be}) in the common emitter circuit consists of:
(NOT IN ECI MATERIALS)
   a. a fixed voltage applied to the collector, a variable voltage applied from base to emitter, a milliameter in series with the collector lead and a VTVM across the emitter-base junction
   b. a variable voltage applied to the collector, a fixed voltage applied from base to emitter, a milliammeter in series with the collector lead and a VTVM across the emitter-base junction
   c. a fixed voltage applied to the collector, a fixed voltage applied from base to emitter, a milliammeter in series with the collector lead and a VTVM across the emitter-base junction
   d. a variable voltage applied to the collector, a variable voltage applied from base to emitter, a milliammeter in series with the emitter lead and a VTVM across the collector-base junction.

100. In order to observe the actual effect of temperature variations on reverse current across the junction:
(NOT IN ECI MATERIALS)
   a. forward bias is applied and, after a period is allowed for stabilization, a small amount of external heat is applied
   b. forward bias is applied and increased until breakdown occurs at which time the temperature is measured
   c. reverse bias is applied and, after a period is allowed for stabilization, a small amount of external heat is applied
   d. reverse bias is applied and increased until breakdown occurs at which time the temperature is measured

QUESTION CORRESPONDENCE BETWEEN PRE-TEST AND POST-TEST

Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test	Pre-Test	Post-Test
1	1	26	30	51	51	76	74
2	4	27	26	52	56	77	75
3	5	28	28	53	54	78	79
4	3	29	29	54	55	79	82
5	2	30	27	55	53	80	81
6	6	31	31	56	52	81	78
7	8	32	35	57	57	82	83
8	12	33	36	58	60	83	80
9	7	34	32	59	61	84	84
10	9	35	33	60	62	85	89
11	10	36	34	61	59	86	90
12	11	37	37	62	63	87	87
13	17	38	38	63	58	88	85
14	18	39	39	64	64	89	88
15	14	40	42	65	66	90	86
16	16	41	40	66	65	91	93
17	13	42	43	67	68	92	92
18	15	43	41	68	67	93	95
19	20	44	44	69	69	94	94
20	22	45	46	70	70	95	91
21	19	46	50	71	71	96	96
22	23	47	47	72	73	97	97
23	24	48	48	73	72	98	98
24	21	49	49	74	77	99	100
25	25	50	45	75	76	100	99

FINAL TEST
Transistors
(100 questions)

1. Germanium and Silicon both have equal numbers of valence electrons in the outer shell, the number is
   (a) 3
   (b) 4
   (c) 5
   (d) 0

2. If we add an impurity to a Germanium Crystal in controlled amounts this procedure would generally be called
   (a) Bias
   (b) Instability
   (c) Chemical
   (d) Doping

3. A pentavolent impurity added to GE or Silicon in proper amounts will cause the crystal to be
   (a) P type
   (b) N type
   (c) PN Junction
   (d) Intrinsic

4. A donor impurity is generally called
   (a) Trivalent
   (b) Pentavalent
   (c) Neutral-ion
   (d) Diffused

5. An acceptor impurity in GE or Silicon Crystal
   (a) Give up an electron
   (b) Take on an electron
   (c) Neutralize the valence band of the crystal
   (d) Move about the crystal at random

6. A PN junction which is forward biased will act nearly like
   (a) An open switch
   (b) A closed switch
   (c) A high resistance
   (d) A battery

7. The area near the PN junction forms a potential barrier and is called the
   (a) Depletion region
   (b) Saturated region
   (c) Cathode potential
   (d) Anode potential

8. The area near the PN junction is ionized as follows
   (a) Negative ions in P side, Positive in N side
   (b) Positive ions in P side, Negative ions in N side
   (c) Equal polarity and quantity of ions are on both sides
   (d) Greater concentration of P ions than N ions

9. Forward biased PN junctions will have the + side of the battery connected to
   (a) The P material
   (b) The N material
   (c) In the center of the junction
   (d) Either P or N without effect

10. Reverse Bias of a PN junction
   (a) Decreases the barrier potential
   (b) Increases the barrier potential
   (c) Causes all current to cease completely
   (d) Is dangerous and should never be used

11. The impurity atoms donors or acceptors placed in the crystal during manufacture
   (a) Are free to move about the crystal structure
   (b) Are neutralized very quickly
   (c) Are locked in the crystal structure by convalent forces and are not free to move
   (d) Are a disadvantage in so far as good transistor operation is concerned.

12. Thermal agitation which releases newly liberated electron - hole pairs
   (a) Causes better transistor action
   (b) Creates more minority carriers which add to I_{CBO}
   (c) Creates more minority carriers which decrease I_{CBO}
   (d) Causes collector current to decrease

13. Normal direction of flow of base lead current in a PNP transistor is
   (a) Always away from the base
   (b) Always toward the base
   (c) Depends on gain and operating point
   (d) Has no important effect on transistor action

14. $I_e - \alpha$fIe will indicate
   (a) Collector current gain
   (b) Base current
   (c) Saturation current
   (d) Operating limitation set by the manufacturer

15. Percentage of impurity added to pure Germanium will change its conductivity. Which of the following percentage of added impurity will reduce the crystal resistance the greatest amount?
   (a) .0001%
   (b) .00001%
   (c) .001%
   (d) 1×10^{-6} %

16. The transistor is more efficient than the tube because
   (a) No warm up time is wasted
   (b) No heater power is required
   (c) It is much smaller
   (d) Less noise is created

17. I_{CO} or I_{CBO} is 6alled
   (a) Saturation or leakage current
   (b) Forward bias current
   (c) DC operating point bias current
   (d) Collector to emitter thermal runaway

18. I_{CO} or I_{CBO} is
   (a) Reverse leakage current collector to base
   (b) Reverse leakage current base to emitter
   (c) Forward bias current collector to base
   (d) Forward bias current base to emitter

19. In a common base configuration the collector current and collector voltage relationship is
   (a) Current gain less than 1 with voltage out of phase
   (b) Current gain greater than 1 with voltage out of phase
   (c) Current gain less than 1 with voltage in phase
   (d) Current gain greater than 1 with voltage in phase

20. A resistor voltage divider across the power supply in most applications is used
   (a) To obtain correct collector voltage
   (b) To obtain the small forward bias voltage required for the collector emitter
   (c) To obtain the small forward bias voltage required for emitter base junction
   (d) To apply a fixed load on the battery for stability.

21. If collector current is .98 ma and the emitter current is 1 ma would a transistor tester indicate:
   (a) Beta factor poor
   (b) Alpha factor normal
   (c) Excessive leakage exists
   (d) Wrong polarity is being applied

22. If the transistor is considered as two rectifiers back to back:
   (a) It could be used to control current in either direction from emitter to collector
   (b) It must always be a one way path for emitter current flow
   (c) There is only one possible circuit configuration that could be used
   (d) One rectifier would have to be turned around to work.

23. The transistor has an input which is a constant voltage equivalent circuit, the output is a constant current equivalent circuit. The entire circuit is usually called a:

(a) Dual parameter equipment circuit
(b) A double ended circuit
(c) A hybrid equivalent circuit
(d) A parametric amplifier

24. h_{ie}, h_{ib}, h_{ic} represents which hybrid parameter:

(a) Current gain of all three circuit configurations
(b) Voltage gain of all three circuit configurations
(c) Figure of noise merit of all three circuit configurations
(d) Input impedance of all three circuit configurations

25. Given the equation Beta = $\frac{\alpha}{1-\alpha}$ what is the value of α if Beta is equal to 40:

(a) .932
(b) .999
(c) .950
(d) .975

26. The power gain in db is 10 log $\frac{P\ out}{P\ in}$ if the log of 5 has a mantissa of .6990 what is the power gain of a circuit having a input of 10 micro watts and an output of 50 milli watts:

(a) + 26.99
(b) - 26.99
(c) + 36.99
(d) + 46.99

27. Tuned tanks in the collector circuit have the collector load tied to a tap on the tank coil for the following important reason.

(a) Maximum frequency response
(b) Minimum distortion
(c) Impedance matching to the next stage
(d) To assure proper bias levels.

28. The output resistance of a PNP transistor in a common emitter circuit is:

(a) The same as tho input
(b) Less than the input
(c) Much greater than the input
(d) Is too small to be measured

29. Draw a CE circuit showing: 1. All resistors required, 2. Bias from a single battery, 3. Meters in each leg (also mark polarity), 4. Place arrows, name and indicate the direction of all three currents. Choose either PNP or NPN transistors.

30. Operating a transistor in a circuit configuration comparative to the grounded cathode tube circuit would be a:
   (a) Common base circuit
   (b) Common emitter circuit
   (c) Common collector circuit
   (d) Oscillator circuit

31. If the emitter by-pass capacitor opens, the gain of the amplifier would:
   (a) Increase
   (b) Decrease
   (c) Would be the same at low but decrease at high frequency
   (d) No noticeable effect

32. The emitter resistor in a conventional transistor amplifier is used as:
   (a) An output load resistor
   (b) Swamping or stabilizing resistor
   (c) Fixed bias resistor
   (d) Regenerative feed back path

33. Conduction of current in a PNP transistor is supported by holes as the majority carriers, current flow is considered to be taking place in the:

(a) Conduction band
(b) Valence band
(c) The forbidden energy band
(d) In the fermi level region

34. The metal most currently used in miniaturized capacitors is:

(a) Aluminum
(b) Tantalum
(c) Mica
(d) Formvar

35. h_{oe} parameter allows calculation of:

(a) Voltage gain
(b) Current gain
(c) Power gain
(d) Output resistance

36. When the impurity content of a PN junction is increased the:

(a) Barrier width is broadened
(b) The depletion region is increased
(c) The Zener breakdown voltage is decreased
(d) The junction tends to run hotter under the same operating points

37. Which rectifier is best suited for high frequency (UHF) range:

(a) Copper oxide
(b) Silicon
(c) Point contact
(d) Photo diode

38. When reverse bias voltage of a PN junction is increased:

(a) Barrier potential is reduced
(b) Ionization is increased
(c) Collector-base junction capacitance is reduced
(d) The barrier potential is effected very slightly

39. Rectification ratio can be found by dividing the:

(a) Reverse impedance by the forward impedance
(b) Reverse current by the forward current
(c) Output voltage divided by the input voltage
(d) Forward impedance by the reverse impedance

40. The energy gap between the valance band and the conduction band for silicon is:

(a) Higher than that of germanium
(b) Lower than that of germanium
(c) Equal to that of germanium
(d) Has no energy gap since it is used as a good transistor material

41. If a power transistor has a maximum temperature limit of 65 degrees C and if thermal drop is 5 degrees C per watt, maximum power allowed at 25 degrees C is:
(a) 4 Watts
(b) 8 Watts
(c) 15 Watts
(d) 2 Watts

42. Which transistor configuration does not give a current gain:
(a) CE
(b) CC
(c) CB
(d) None of the three

43. The beta factor corresponds to which of the following parameter?
(a) h_{oe}
(b) h_{ob}
(c) h_{fe}
(d) u_{re}

44. The most useful semiconductor elements for transistor crystals are:
(a) Pentavalent
(b) Trivalent
(c) Telravalent
(d) Intravalent

45. The solid state rectifier loses its rectifying ability because:
(a) The barrier resistance increases rapidly
(b) The barrier capacitance decreases
(c) The barrier capacitance shunts the signal
(d) The barrier is open circuited for high frequencies

46. If collector current change is 1 ma and the change of base current is 20 micro-amps then:
(a) Alpha gain is 20
(b) Beta gain is 20
(c) Beta gain is 50
(d) Alpha gain is 50

47. Given the equation $B = \frac{\alpha}{1-\alpha}$ if α = .975 then Beta equals:

(a) 97.5
(b) 9.75
(c) 39.0
(d) 3.90

48. The point-contact transistor has:
(a) A high power handling capability
(b) A high noise figure
(c) Low frequency rectifier response
(d) High current capability

49. The transistor is a current controlled device because:
(a) Base voltage has no effect on collector current
(b) Base voltage is not stable
(c) I_c is controlled by I base (base current)
(d) Emitter base junction forms a high impedance

50. For a PNP transistor:
(a) The collector is positive with respect to the base
(b) Electron current flow is from the collector to the emitter
(c) The majority carriers are electrons
(d) The base is P type semi-conductor material

51. Reading a Beta of 40 on a transistor tester at room temperature:
(a) Beta will go above 40 if transistor is heated
(b) Beta will fall below 40 if heated
(c) Beta will remain the same if heated
(d) Tester reading is immune to temperature change in transistor

52. A CE configuration in an <u>NPN</u> transistor has the emitter grounded and + 9 volts is measured at the collector, a possible proper voltage bias at the base is:
(a) -0.5 volts
(b) + 10 volts
(c) - 10 volts
(d) + 0.5 volts

53. From 92% (to 99%) of the emitter current passes through the base to the collector because:
(a) The base is more heavily doped with impurities than the emitter
(b) The collector base is forward BIASED
(c) Carrier generation in the base is high
(d) Only a few emitter carriers recombine in the base

54. Except for the charge, the hole has a nature corresponding to that of:
(a) A photon
(b) A proton
(c) An electron
(d) A neutron

55. If the collector has an inductive load and the maximum collector voltage listed by the manufacturer is 25 volts max. the collector BATTERY voltage should not exceed:
(a) 10 volts
(b) 12.5 volts
(c) 25 volts
(d) Twice the maximum allowed

56. If a PN junction rectifier passes 4 micro amps with 1 volt of reverse bias and 10 milli-amps with 1 volt forward bias, what is its rectification ratio?
(a) 250
(b) 400
(c) 2500
(d) 4000

57. A VR tube has an operating region where current can vary from 5 - 30 ma. approximately and voltage will remain constant, what semiconductor will perform a similar function?
(a) Forward biased diode
(b) Tunnel diode
(c) Zener diode
(d) A diode operating beyond the maximum temperature operating limits

58. A simple check of a transistors condition can be made with an ohm meter. What precaution must be closely observed?
(a) Wrong polarity
(b) Application of test leads to improper transistor leads
(c) Proper R multiplier range to prevent excessive voltage and/or current.
(d) Definite assurance whether the transistor is a PNP or an NPN

59. A regulated DC power supply having an output with negative ground is usually controlled by a Zener diode with:
(a) The cathode at negative ground
(b) the anode at positive ground
(c) The anode at negative ground
(d) The Zener voltage above the maximum regulated output voltage

60. To compensate for temperature drift versus stabilized Zener voltage:

(a) A junction diode with negative temperature coefficient is placed in shunt with the Zener diode.
(b) Two Zener diodes are hooked back to back.
(c) A junction diode with positive temperature coefficient is placed in series with the Zener diode.
(d) A junction diode with negative temperature coefficient is placed in series with the Zener diode.

61. Using the equation P = E x I a 50 watt zener working at 62 volts regulation will handle __________ milli-amps of current if temperature is not considered:

(a) 8.06 milli-amp
(b) 80.6 milli-amp
(c) 806. milli-amp
(d) .0806 amperes

62. The current versus voltage curve of a Zener diode most nearly matches the curve of:

(a) A Thyratron tube
(b) A neon tube
(c) A beam power tetrode
(d) A VR tube

63. The reverse breakdown voltage of a PN junction can be checked with essentially the same test circuit as that used for a Zener diode:

(a) True
(b) False
(c) Has no similiarity
(d) Would ruin the PN junction

64. The Zener diode has a distinct advantage over the conventional voltage regulator tube because:

(a) It is smaller in size and can be obtained with a wide range of Zener voltages.
(b) It is more stable with temperature changes
(c) The VR tube cannot be used in series
(d) Its breakdown voltage can be adjusted with proper bias

65. A good Zener diode could be used as:

(a) A regulator or a rectifier
(b) A regulator or an amplifier
(c) A regulator or an oscillator
(d) None of the above combinations since it is only a regulator.

66. If the external feed-back circuit cancels both the resistive and the reactive changes in the input circuit, the circuit is said to be:

(a) Neutralized
(b) Resonant
(c) Balanced
(d) Unilateralized

67. Since a change in output voltage of a transistor amplifier is coupled internally back to the input the circuit is likely to:

(a) burn up
(b) Cut off
(c) Sustain self oscillations
(d) Operate entirely in the saturated region

68. If an inductor of 8 micro-henry in a tuned tank is increased by a factor of 100 to obtain a high Q, the capacitor in order to retain the original resonant frequency must be:

(a) Increased by a factor of 100
(b) Decreased by a factor of 100
(c) Increased by the $\sqrt{100}$
(d) Decreased by the $\sqrt{100}$

69. A microphone is fed to a transistor pre-amplifier. In order to keep the signal to noise ratio factor low, the operating bias should, be chosen that:

(a) A small emitter current with very low collector voltage exists
(b) A large emitter current regardless of collector voltage occurs
(c) The transistor will operate in the center of its maximum current limits.
(d) The microphone will not be damaged

70. The collector is usually tied to a tap on the coil of tuned output tank to:

(a) Insure proper bias
(b) Obtain the least distortion
(c) Obtain maximum power transfer
(d) Prevent fly-back voltage from exceeding the collector emitter voltage maximum

71. Cross-over distortion in a class B push-pull amplifier can be eliminated by:

(a) Exact matching of transistors
(b) Good temperature stability compensation
(c) Placing a small forward bias voltage on each transistor
(d) Placing a small reverse bias voltage on each transistor

72. Two outputs from a single stage, one from the collector resistor and one from the emitter resistor is known as a:
   (a) Single stage modulator
   (b) Single stage detector
   (c) Single stage phase splitter
   (d) Single stage oscillator

73. The above stage will eliminate the need for:
   (a) Coupling Capacitors to a push-pull stage
   (b) Bias batteries to a push-pull stage
   (c) Center tapped transformer to a push-pull stage
   (d) Temperature compensation

74. Bandwidth is equal to the resonant frequency divided by the Q of the tank circuit. What is the Q of the circuit if the BW is 10 KC and the IF resonant frequency is 455 KC?
   (a) 455
   (b) 45.5
   (c) .022
   (d) 22.

75. Resonant frequency equals one over 2π times the square root of LC. What is the resonant frequency of a tank having a coil of 9 milli-henries and a capacitor of .001 micro-farads.

   (a) ______________________ CPS

76. What will be the resonant frequency if the coil in problem 75 is increased 4 times (to 36 milli-henries)?

   (a) ______________________. CPS

77. Complimentary symmetry circuits do act as push-pull and use:
   (a) Matched transistors of identical types
   (b) One NPN and one PNP
   (c) One transistor in conduction at all times
   (d) Tuned tanks

78. The greatest advantage of complimentary symmetry circuit over regular push-pull is:
   (a) It requires no bias or temperature compensation
   (b) It requires no phase inverter or center tapped transformer for drive
   (c) It can handle greater power with less current drain
   (d) Less distortion with higher frequency response

79. What type circuit will allow a linear rise of collector current for any proportional change of increased emitter current or a linear amplification factor over a wide range of emitter current?
   (a) Push-pull
   (b) Complimentary symmetry
   (c) Compound
   (d) Phase inverter

80. A transistor oscillator circuit having a power gain less than one would produce:
(a) A stable sine wave at any desired frequency
(b) A sine wave whose amplitude will increase progressively
(c) A distorted ringing wave with negative alternations flattened
(d) A sine wave whose amplitude progressively weakens and disappears.

81. A transistor oscillator requiring a starting power of 2 milli-watts has a power gain of 20. If the feedback network loss is 8 milli-watts, the optimum total feedback power to sustain oscillation must be:
(a) 22 milli-watts
(b) 2 milli-watts
(c) 10 milli-watts
(d) 28 milli-watts

82. In question 81 the power delivered to the load is output power less the feed back power. How many milli-watts is available for load power?
(a) 22
(b) 12
(c) 30
(d) 48

83. In an amplifier circuit feed back from the output to the input through the collector base capacitance and the base spreading resistance will result in:
(a) Negative feedback which aids the signal
(b) Negative feedback which causes oscillation
(c) Positive feedback which degenerates the signal
(d) Positive feedback which aids the signal and causes oscillation

84. TC = RC. How much time would it take to charge a .01 mfd. capacitor to the applied voltage E through a 5K resistor?
(a) 25 milli-sec.
(b) 500 micro-sec.
(c) 50 micro-sec.
(d) 250 micro-sec.

85. If the applied voltage E of question 84 was 50 volts, how much voltage would be across the capacitor in 1/5 of the time for the answer you computed in the previous question?
(a) 6.3 volts
(b) 5 volts
(c) 10 volts
(d) 31.6 volts

86. An output circuit with a resistive load produces a perfect sine wave having a peak to peak voltage of 24 and a peak to peak current 32 milli amps. How much AC power output does this represent? If power equals E x I (RMS Value) in a resistive load:

(a) 9.6 watts
(b) 96 micro watts
(c) 96 milli watts
(d) .9 watts

87. If we consider a transistor as a current operated device, if electrons were removed from the base of a PNP transistor by signal action, would:

(a) The emitter current increase
(b) The collector current decrease
(c) The conductivity of the base decrease
(d) The barrier potential at the junction reverse polarity

88. A stable transistor audio oscillator having no resonant circuit is called:

(a) A Hartley Oscillator
(b) A Colpitts Oscillator
(c) A Modified Hartly Oscillator
(d) An RC phase shift oscillator

89. Normal cross over distortion in a push-pull output stage is caused by operating the stage:

(a) with zero bias
(b) with too much bias
(c) with reverse bias
(d) with too high a collector voltage

90. In an emitter-follower or CC circuit, the output signal would be greatest across the emitter resistor if:

(a) A 10 ufd capacitor is shunted across the resistor
(b) A 100 ufd capacitor is shunted across the resistor
(c) A .1 ufd is shunted across the resistor
(d) If the capacitor were omitted

91. The low frequency response of a transistor video amplifier is mainly due to the:

(a) Coupling capacitor
(b) Stray input capacitor
(c) Peaking coil too large
(d) Peaking coil too small

92. A good sine wave input to a transistor circuit results in symmetrical amplified square wave. This would indicate that:

(a) The signal input is correct but the transistor is operating too near the bottom of the load line.

(cont'd. over)

92. Cont'd.

(b) The signal input is correct but the transistor is operating too near the top of the load line.
(c) The signal is overdriving the transistor and the bias position is about in the center of the load line.
(d) The signal is correct but the transistor is leaking excessively

93. What does Si represent?

(a) Current at maximum temperature
(b) Current at ambient temperature
(c) Current stability with change of temperature
(d) Safety factor specified by manufacturer

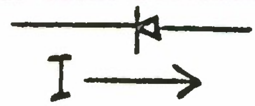
94. Operation of a transistor switch in the heavy saturation region will:

(a) Cause stored carriers in the emitter region and delay turn-off time
(b) Cause stored carriers in the base which delays turn-off time and decreases the pulse repetition rate
(c) Reverse bias the base collector junction allowing faster turn-off time
(d) Forward bias the collector base junction and increase the depletion region at the junction barriers

95. Which symbols make a matched set of parameters?

(a) h_{ie}, h_{12}, r_i, h_{22}
(b) h_{fe}, B, α_{fe}, h_{21}
(c) h_{oc}, h_{11}, mho
(d) h_{21}, h_{ie}, S_v, μ_{re}

96. Draw a simple diagram showing a transformer whose secondary feeds a bridge rectifier using 4 silicon diodes. Add a load resistor and one electrolytic capacitor. Mark the polarity of the electrolytic capacitor as you would actually build the circuit. Use electron flow theory assuming current flow in the diode rectifiers is against the arrow.



97. Switching circuits that use double diode clamping to prevent both saturation and cut-off requires important consideration of:

(a) Matched diodes to insure proper operation
(b) The size of base drive current and input signal
(c) The load line so as not to exceed the transistor power dissapation curve
(d) The range of switching frequency that both diodes and transistor can effectively operate at.

98. An abrupt change of input signal from $+ 14$ to $+ 10$ volts indicates a:

(a) Positive step function
(b) Negative step function
(c) Battery deterioration condition
(d) A differentiated pulse

99. On a typical transistor (CE) characteristic curve, a small collector current with base drive current at zero, is caused by:

(a) Improper bias
(b) H_{fe}
(c) I_{cbo}
(d) Short in one of the transistor junctions

100. $I_{ceo} = I_{cbo} (1 + \alpha_{fe})$. What is I_{ceo} if I_{cbo} is 5 micro amps and the forward current amplification factor of a PNP is 32 and how can I_{ceo} be reduced?

(a) 160 micro amps and can be reduce by placing a large R in the base lead
(b) 160 micro amps and can be reduced by placing a small coil in the base leads
(c) 165 micro amps and can be reduced by a small R or L in the base lead
(d) 165 micro amps and can be reduced by increasing the collector load resistance.

APPENDIX IV

EXPERIMENTAL DATA

<u>DATA OBTAINED DURING 24-HOUR EXPERIMENT FROM</u>

(1) Control Group (Using Conventional Instruction)

(2) Experimental Group I (Using Self-Sufficient Multi-Media Materials Developed by RCA)

(3) Experimental Group II (Using Self-Study Material Selected from U. S. Air Force Extension Course Institute Course 3032 <u>Fundamentals of Solid State Devices</u>

DATA CONTAINS INFORMATION CONCERNING

(1) OTIS Test Scores

(2) Pre-Test - Post-Test Scores on entire 100-Test Questions

(3) Pre-Test - Post-Test Scores after deleting five questions not covered in Extension Course Institute Course (Questions deleted from both tests - 49, 57, 98, 99 and 100)

(4) Summary of Time and Attendance Records obtained during experiment

CONTROL GROUP DATA
(Using Materials Normally Taught in Solid State Course)

CONTROL EXPERIMENTAL SUBJECTS		MEASUREMENT INFORMATION ON CONTROL COURSE (100-QUESTION TEST)					MEASUREMENT INFORMATION ON CONTROL COURSE (95-QUESTION TEST)					TIME AND ATTENDANCE INFORMATION ON CONTROL COURSE			
	OTIS	PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	TOTAL CLASS HOURS	OUTSIDE STUDY	DISCUSSION	TOTAL STUDY HOURS
C-1	57	58	85	27	42	.643	54	80	26	41	.634	18	0	0	18
C-2	54	49	75	26	51	.510	46	71	25	49	.510	24	11	0	35
C-3	49	64	92	28	36	.778	61	87	26	34	.765	24	10	0	34
C-4	46	69	88	19	31	.613	66	83	17	29	.586	24	4	0	28
C-5	46	63	88	25	37	.676	60	84	24	35	.686	18	3	0	21
C-6	45	64	75	11	36	.306	60	70	10	35	.286	24	0	0	24
C-7	41	64	90	26	36	.722	61	85	24	34	.706	24	4	0	28
C-8	39	33	83	50	77	.649	33	79	46	62	.742	24	6	0	30
C-9	39	52	76	24	48	.500	51	71	20	44	.455	24	2	0	26
C-10	38	58	83	25	42	.595	57	80	23	38	.605	21	4	0	25
C-11	36	33	66	33	77	.429	31	61	30	64	.469	24	4	0	28
C-12	32	42	73	31	58	.534	40	70	30	55	.545	24	12	0	36
Means (N=12)	43.5	54.1	81.2	27.1	47.6	.5796	51.7	70.9	22.6	43.3	.5824	22.7	5	0	27.7

EXPERIMENTAL GROUP I DATA
(Using Self-Sufficient Multi-Media Materials)

EXP I (RCA) EXPERIMENTAL SUBJECTS	OTIS	MEASUREMENT INFORMATION ON EXPERIMENTAL COURSE (100-QUESTION TEST)					MEASUREMENT INFORMATION ON EXPERIMENTAL COURSE (95-QUESTION TEST)					TIME AND ATTENDANCE INFORMATION ON EXPERIMENTAL COURSE			
		PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	TOTAL CLASS HOURS	OUTSIDE STUDY	DISCUSSION	TOTAL STUDY HOURS
R-1	62	53	89	36	47	.766	52	84	32	48	.667	21.3	0	0	21.3
R-2	54	59	88	29	41	.707	57	83	26	43	.605	32.1	0	0	32.1
R-3	49	43	69	26	57	.456	41	67	26	59	.441	36.1	3	1	40.1
R-4	47	25	79	54	75	.720	24	74	50	76	.658	25.8	0	0	25.8
R-5	46	65	80	15	35	.429	60	75	15	40	.375	21.8	2	0	23.8
R-6	44	66	85	19	34	.559	64	81	17	36	.472	24.8	0	0	24.8
R-7	41	52	92	40	48	.833	50	87	37	50	.740	27.9	2.5	0	30.4
R-8	39	60	80	20	40	.500	58	75	17	42	.405	29.1	0	0	29.1
R-9	38	36	79	43	64	.672	34	74	40	66	.606	35.5	4	2	41.5
R-10	37	35	48	13	65	.200	33	45	12	67	.179	36.2	0	0	36.2
R-11	36	51	61	10	49	.204	48	56	08	52	.154	33.3	0	0	33.3
R-12	34	66	73	7	34	.206	62	70	08	38	.211	31.3	0	0	31.3
Means (N=12)	43.9	50.9	76.9	26.0	49.1	.5210	48.6	72.6	24.0	51.4	.4594	29.7	1.4	.25	31.4

EXPERIMENTAL GROUP II DATA
(Using Extension Course Institute Materials)

EXP II (ECI) EXPERIMENTAL SUBJECTS		MEASUREMENT INFORMATION ON EXPERIMENTAL COURSE (100-QUESTION TEST)					MEASUREMENT INFORMATION ON EXPERIMENTAL COURSE (95-QUESTION TEST)					TIME AND ATTENDANCE INFORMATION ON EXPERIMENTAL COURSE			
	OTIS	PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	PRE-TEST	POST-TEST	GAIN	POSSIBLE GAIN	RATIO-GAIN	TOTAL CLASS HOURS	OUTSIDE STUDY	DISCUSSION	TOTAL STUDY HOURS
E-1	65	56	77	21	44	.477	56	75	19	39	.487	21	0	0	21
E-2	58	71	80	9	29	.310	66	75	9	29	.310	21	0	0	21
E-3	49	70	92	22	30	.733	67	87	20	28	.714	24	0	0	24
E-4	46	42	57	15	58	.259	42	55	13	53	.245	24	20	5	49
E-5	45	54	66	12	46	.261	50	61	11	45	.244	21	0	0	21
E-6	45	48	78	30	52	.577	45	74	29	50	.580	24	6	0	30
E-7	41	34	61	27	66	.409	32	58	26	63	.413	27	3	1	31
E-8	41	46	50	4	54	.074	44	46	2	51	.039	24	2	0	26
E-9	39	49	53	4	51	.078	45	51	6	50	.120	24	0	0	24
E-10	37	24	44	20	76	.263	24	41	17	71	.239	27	6	1	34
E-11	36	86	88	2	14	.143	81	83	2	14	.143	24	20	0	44
E-12	31	64	68	4	36	.111	62	64	2	33	.061	24	25	4	53
Means (N=12)	44.4	53.7	67.8	14.2	46.3	.3079	51.2	64.2	13.0	43.8	.2996	23.7	6.7	.9	31.5

APPENDIX V

EXPERIMENTAL GROUP I

TIME AND ATTENDANCE RECORD

EXPERIMENTAL GROUP 1

TIME AND ATTENDANCE RECORD

SUBJECT	DATE AND TIME*																			Total Time	Pre-Test Score	Post-Test Score	Poss. Gain	Actual Gain	Gain Ratio	Inter-viewed
	1/27	1/28	2/1	2/2	2/3	2/4	2/7	2/8	2/9	2/10	2/11	2/15	2/16	2/17	2/18	2/21	2/23	2/24	2/25							
Group A (Tues. & Thur. A.M.)																										
R-A	3:30		3:25		3:25			3:25		3:10		3:15				3:30		1:00		24:40	09	50	91	41	.450	X
R-7	3:30		3:45		3:25			3:15		3:10		3:20		3:30		3:30		0:30		27:55	52	92	48	40	.833	X
R-F																					41		59			
R-9	3:30		3:45		3:40			3:15		3:15		3:35	3:25	3:30	3:05	3:45		0:45		35:30	36	79	64	43	.672	X
R-B	3:30		3:45		4:00			3:15		3:10		3:35	3:25	3:30		3:45		1:30		32:25	15	61	85	46	.541	X
R-D	3:30		3:45		3:25			3:30		3:20		3:30		3:36	2:00	3:45		1:05		31:20	40	78	60	38	.633	X
Group B (Tues. & Thur. P.M.)																										
R-8	3:20				3:10	3:00		3:10		3:00				3:00				3:00	3:05	24:45	66	85	34	19	.559	
R-1	3:25				3:30		2:00	1:40		3:25		3:15		3:20				0:45		21:20	53	89	47	37	.778	
R-E	3:15				3:10	3:05		2:15		3:15		3:20		3:10		3:30		3:30		28:30	46	77	54	31	.574	
R-12	3:30				2:50	3:10		3:10		3:25		3:20		3:30		3:10		3:15	2:00	31:20	66	73	34	07	.206	
R-10	3:20				3:00	3:15		3:15		3:00		3:10	2:45	2:50	2:35	3:00	3:15	2:45		36:10	35	48	65	13	.200	
R-4	3:20				3:20		2:20	3:15		3:05		2:55		3:00		3:00		1:30		25:45	25	79	75	54	.720	X
Group C (Wed. & Fri. A.M.)																										
R-5		3:30		3:30		3:30			3:30		3:35		3:30				0:45			21:50	65	80	35	15	.429	X
R-C		3:35		3:30		3:25			3:30		3:35		3:30				3:15			24:20	84	98	16	12	.750	X
R-2		4:15							6:40		7:35		8:40		4:10		2:45			32:05	59	88	41	29	.707	X
R-11		3:40		3:30		3:40			3:20		5:50		4:45		4:00		4:30			33:15	51	61	49	10	.204	
R-3		2:45		4:15		3:35			6:15		5:00		5:10		5:15		3:50			36:05	43	69	57	26	.456	X
R-8		3:20		3:30		3:15			3:25				6:10		6:05		3:20			29:05	80	80	40	20	.500	

*Time in Hours and Minutes

APPENDIX VI

EXPERIMENTAL GROUP I

INTERVIEW QUESTIONS

AND

SUBJECT INTERVIEWS

The interview questions follow:

1. What did you think of the course?

2. Did you experience any difficult areas? Can you suggest any improvements?

3. What parts of the course did you like most? Why?

4. Would you like to take other courses on other subjects using this method of instruction?

5. What aspects of the course did you particularly dislike, or liked the least? Why?

6. Do you feel you learned something from this course? Very little, some a great deal?

7. Have you ever studied transistors or semiconductor principles before? Formal course, correspondence or on your own.

8. Do you particularly like self-study at your own rate, such as in this course, or would you rather attend formally conducted class sessions?

9. Do you feel you could gain very much more by going back through the course again?

10. Do you think the directions contained in the program were adequate? That is were they clear, understandable, and did they occur at the right places?

11. In your opinion were the pictures and/or illustrations adequate and pertinent to the particular area under discussion? If so do you think the pictures helped you to learn certain concepts? Could you have done almost as well without pictures?

12. Did you like the break-up of the course into the different learning methods or did you find this confusing and distracting from learning the material?

13. Do you feel you are now capable of performing at least limited maintenance and repair of transistorized devices?

14. Did you do any studying outside of class? Approximately how much?

15. Related subject discussion? How much? With whom (other student, other)?

The following is a summary of the comments made by those subjects interviewed from Experimental Group I at the conclusion of the experimental portion of the course.

Subject No. 1

This subject indicated he liked section G the best. In this section Diode and Transistor Behavior was studied utilizing the RCA 601-T Transistor Trainer and the Audio Graphic Instructor. The section which interested him the least was section D, Principles of Transistor Action. The medium employed in this section was the cued text. This subject feels he learned a lot and prefers self-study at own rate to formal classroom instruction. He felt the pictures used in the audio visual portion of the course was very helpful and necessary. The instructions for course procedures were adequate and posed no problems. This subject did exercise his option of outside study and studied for approximately two hours from TM 11-690.

Subject No. 2

This subject likes multi-media instruction very much. He feels he was well motivated and believes he could analyze circuit behavior and perform minor trouble-shooting with the knowledge gained. He felt in some areas the picture and text material could be improved, he did not care for the female voice used in review and felt there were too many programmed stops. Also, he would suggest an index for review to permit ease of backing-up to a particular area and have the tape program supplemented in the training manual for review. The subject indicated that for the most part reviewing the training manual was adequate for preparing for the examinations. No outside study or discussions was required.

Subject No. 3

This subject likes and enjoys the self-pacing self-study and in particular the audio visual portion of the course. He had difficulty in section G both in trainer tolerances and in following aural instructions. He believes he can get as much out of self-study as he could from an instructor. He definitely learned from the program and feels he could learn more if he repeated the course. Instructions for procedures were adequate, pictures in AV portion were necessary and multi-media self-study courses free the student from the instructor. Suggest that section G instructions appear in training manual

instead of aural. The subject does not think he is capable of transistor maintenance but could perform limited circuit analysis. He spent approximately five hours in outside study and one and one-half hours in discussions.

Subject No. 4

This subject liked the course and the variations in presentation however, he would prefer fewer media. He did not like the programmed learning, felt it was "too rote", but he did enjoy working on the trainer (RCA 601-T). Would be interested in other courses employing various media if they were not completely theoretical. He felt he learned a great deal but would not benefit too much if repeated. The procedure directions were adequate and the pictures were necessary. The subject indicated he thought the course taught how transistors really work and feels he could do limited maintenance. He suggests that portions of section D the cued text medium could be better organized. He spent approximately three hours in outside study using TM-11-690 and about one hour of outside discussions.

Subject No. 5

This subject thought the course was pretty good. He enjoyed the portions of the course which employed the audio visual and movie media, but he did not like the cued Text medium of instruction. The subject likes self-study except for portions involving reading and did not like the programmed text due to worrying about exact wording in his response. He felt he learned quite a bit but would gain very little more by repeating the course. All instructions for proceeding in program were simple to understand, pictures were definitely necessary. He would like to see more practical work and a method of indexing the tapes to permit rapid access to a particular area for review. This subject felt the course would help him to troubleshoot transistor circuits. He spent approximately two and one-half hours in outside study.

Subject No. 6

This subject indicated that he liked taking the multi-media self-study course and would have preferred more practical work. He feels the ability to repeat certain parts of the course and to proceed at own rate helped him learn the course material. He would like an instructor supplemented self-study course or self-study course with capability for discussion as necessary.

Procedural instruction was adequate and all pictures were necessary. The subject feels he learned quite a bit and that the knowledge gained would definitely help in transistor circuit maintenance. He spent approximately four hours in outside study and two hours in discussions.

Subject No. 7 and No. 8 (These two subjects were interviewed together).

Both subjects indicated they liked the audio visual portion of the course the best and felt the experiment set-up was difficult. The experiments referred too are the practical applications of transistors using the RCA 601-T trainer in section G of the course. They liked the variety of media but would have preferred a combination of self-study and instructor presentation. No problem following procedural instructions. Both learned quite a bit and feel they could gain more by repeating the course. One of the subjects indicated he got lost toward end of course. He also would have liked to take the training manual with him outside of class, this was not permitted by any subjects in Experimental Group I (RCA). The subjects both felt they could now work with transistors.

Subject No. 9

This subject's AV machine malfunctioned, as a result he had more interruptions then necessary in the program. He would have preferred self-study at home, thus fewer distractions. Could have used more programmed steps in the AV portion of section G. He likes the use of multi-media instruction and feels he learned a great deal the first time through the course. Procedural direction was adequate. The subject would have liked to see more pictures, charts and diagrams used. He feels he can now tackle transistor circuitry. No outside study or discussions were required.

Subject No. 10

This subject likes multi-media instruction and felt a good part of his learning took place in section G of the course (practical application portion). He would like a self-study course supplemented by an instructor, however, if paying for the course he would prefer a course presented by an instructor. The subject indicated he learned a great deal, would not gain much more by repeating, and would be able to work on transistor devices. Instructions were adequate although the subject had to repeat some of the instructions because they were missed. He suggests a pre-warning before the instruction is given. No outside study or discussion were necessary.

Because of student time availability limitations, only 10 students were interviewed.

The predominant reaction to the program was enthusiasm. As might be expected there were differences of opinion as to which medium appealed to the different students. The medium liked best by the majority was the audio-visual while the media liked least was the linear programmed text and the cued text material. Without exception all interviewees liked the multi-media method.

APPENDIX VII

SCORES OBTAINED ON FINAL EXAMINATION

(CONTROL GROUP, EXPERIMENTAL GROUP I
AND EXPERIMENTAL GROUP II)

Scores Obtained by the Control and Experimental Groups on the Final Examination Administered Upon Completion of Entire 102 Hours of Training.

Subject	Control	Exp I (RCA)	Exp II (ECI)
1	-	91	-
*2	77	84	75
*3	87	78	89
4	98	78	-
*5	93	75	73
6	88	-	79
*7	85	94	59
8	-	70	48
*9	75	69	53
10	-	66	-
*11	75	70	95
12	-	77	-

*Blocks used in analysis of variance

APPENDIX VIII

ATTENDANCE RECORD DURING LAST 78 HOURS OF INSTRUCTION

(CONTROL GROUP, EXPERIMENTAL GROUP I AND EXPERIMENTAL GROUP II)

Total Number of Hours of Attendance for Each Subject in the Matched Groups During the Final 78 Hours of Instruction

Subject	Control	Exp I (RCA)	Exp II (ECI)
1	54[d]	72	0[d]
2	69	75	75
3	69	69	78
4	75	75	76[i]
5	78	69	69
6	78	51[d]	69
7	72	78	75
8	60[i]	75	69
9	72	78	72
10	0[d]	69	0[d]
11	78	75	75
12	72[i]	75	0[d]

d Dropout

i Incomplete (no final test or late final test)

APPENDIX IX

SAMPLE OF "CUED" TEXT

PART 4

TRANSISTOR FABRICATIONS

The two materials most generally used in the construction of transistors, germanium and silicon, must be refined to a high degree of purity. One of the final steps in their purification process is the **zone-melting** technique. This technique refers to locally melting a portion of a bar of germanium or silicon using an induction heating coil. As the coil is moved slowly down the bar of semiconductor material the melted portion moves with it. The germanium and silicon directly beneath the coil is melted by the high frequency field. As the coil is moved along the bar melting a new portion, the cooling semiconductor material solidifies and regrows into a highly purified single crystal of germanium or silicon. The impurities are swept along in the melted portion to the end of the bar where they are removed.

As discussed earlier in your course highly purified germanium or silicon is as undesirable as impure material. Therefore, the now pure semiconductor material must be **doped** with a controlled amount of known impurities. Doping may be accomplished in several ways, the most common being the grown transistor method. In this method the germanium or silicon is placed in a graphite crucible and melted using radio frequency power. Once melted, a perfectly formed crystal called the seed is placed in contact with the melt. As the seed is slowly drawn away the melted germanium or silicon adheres to the seed and solidifies forming a crystal. If the molten material in the crucible is properly doped during the growing process then either N or P type semiconductor material is obtained. Doping must be precise; the weight of controlled impurities added are less than one ten-millionth the weight of the crystal.

Extreme care must be taken throughout the growing process to ensure the desired results. If properly grown, a single crystal of semiconductor material is obtained. This means all of the atoms are properly aligned and each part has identical structural characteristics.

1 At present, three doping methods are in use. The first is the formation of an alloy of the germanium or silicon and of the donor or acceptor substance. An alloy is formed when the melt is **doped** with a particular impurity as the crystal is being grown.

2 The second method is to change the impurity concentration as the crystal is being grown. The impurity concentration increases in the melt as the crystal grows since most impurities tend to remain in the melt. The amount of impurity which enters the freezing crystal depends upon the melt temperature. By placing both N and P impurities into the melt and changing the rate of growth (melt temperature) at specified times, PN junctions are formed in the growing crystal.

3 The third method is a diffusion technique. While the crystal lattice remains a solid the impurity is melted onto the crystal, at a temperature of approximately 650° (F) for germanium and 1100° (F) for silicon. Diffusion can also be accomplished by placing the germanium or silicon in a gaseous atmosphere which contains the specified impurity and applying heat. Or the crystal may be coated with a solution of the impurity and heated. The diffusion process is very slow requiring several hours to complete.

Alloy Transistors

The alloy transistor is constructed using a crystal of N or P type material cut into a wafer approximately the size of the typed letter O and shaved to a thickness of three sheets of paper from your training manual. To construct a PNP type alloyed transistor the wafer would be cut from a germanium crystal. Then an impure metal chip, such as indium, aluminum or antimony is alloyed into the **opposite** faces of the wafer. As the molten impure metal chip comes in contact with the germanium wafer, it is melted in that region and mixes with the metal. In cooling the germanium returns to its original crystalline form highly doped by the impure metal. A line drawing of this construction is seen in Figure D-24.

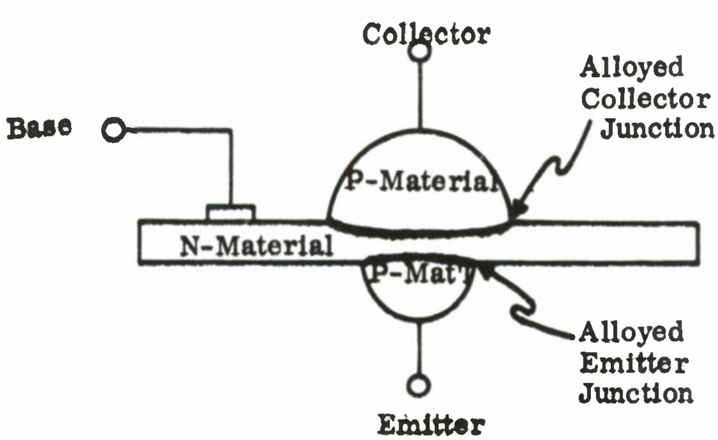


Figure D-24. Typical Alloyed-Junction Transistor

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13. ABSTRACT

A completely automated multi-media self-study program for teaching a portion of electronic solid-state fundamentals was developed. The subject matter areas included were fundamental theory of transistors, transistor amplifier fundamentals, and simple mathematical analysis of transistors including equivalent circuits, parameters, and characteristic curves. The media included a tape slide audio-visual presentations, a programmed text, a cued text, a sound movie, a workbook, an a RCA transistor trainer. A controlled experiment was conducted, comparing the effectiveness of the self-sufficient multi-media materials, with a conventional instructor/classroom presentation and existing self-study materials from Air Force Extension Course Institute. Even though the instructor/classroom subjects received somewhat higher ratio gain scores, on the average, than the multi-media subjects, this difference was not significant. Both of these modes were superior in effectiveness to the extension course materials. The principal measures of this effectiveness were a pre-test and a post-test made up of multiple choice items concerning the solid state theory covered.

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Security Classification

14. KEY WORDS	LINK A		LINK B		LINK C	
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